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The economic impact of broadband and digitization through the COVID-19 pandemic

Econometric modelling

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Foreword

Over the past year, the whole world has been living through a seismic social and economic shift caused by the outbreak and continued spread of the COVID-19 pandemic. The global health crisis has brought many challenges in its wake, but it has also had the effect of galvanizing cooperation across the digital ecosystem, bringing our community together and offering opportunities to explore new policy and regulatory models and adopt more agile and flexible approaches to promoting inclusive connectivity and shoring up digitally-led economic resilience.

Building on ITU's global and regional economic research, which was based on datasets ending in 2018 and was published in 2020, the following study relies on the same structure and econometric models, but in this case examines the impact of fixed and mobile broadband penetration and digitization levels on the global economy through to the end of 2020, in an effort to measure the contribution of digital to social and economic resilience.

With the theme of ***Connecting the unconnected to achieve sustainable development***, ITU's forthcoming World Telecommunication Development Conference (WTDC) will focus particularly on effective strategies to drive digital inclusion at a time when being connected has never mattered more. The results of this study will serve as an important contribution to those discussions and debates, offering solid data-based evidence on the economic impact of the COVID-19 pandemic on the ICT sector itself, as well as the implications for strategies to drive inclusive connectivity and reach out to underserved communities worldwide.

The expert analyses presented in this new report are based on solid empirical evidence, providing an invaluable global picture of the role digital technology is playing in mitigating the social and economic disruption caused by the COVID-19 pandemic. I hope its findings will be useful to ITU members around the world in supporting their national decision-making, as they strive to define a "new normal" and reshape their post-COVID-19 economies.

Doreen Bogdan-Martin
Director, ITU Telecommunication Development Bureau

Executive summary

A study published by the ITU Telecommunication Development Bureau in 2020, entitled "How broadband, digitization and ICT regulation impact the global economy", supported by econometric models built on data collected from 139 countries between 2007 and 2018, provided significant evidence on the importance of information and communication technologies (ICTs) as contributors to economic growth, productivity, and employment.[1] Since the publication of that research, the outbreak of COVID-19 has raised two critical policy questions:

- Given the changes in the deployment, adoption and use of ICTs since the beginning of the pandemic, has their economic contribution remained at the same level as measured before the occurrence of the pandemic?
- Can ICTs increase countries' economic resilience to the pandemic?

Building on the study published in 2020, the following research relies on similar econometric models and examines fixed and mobile broadband, as well as the impact of digitization on the economy, through to the end of 2020 (rather than 2018), and assesses their contribution to increasing economic resilience to face the pandemic.

COVID-19 drove several changes in ICT investment, deployment and service adoption trends in 2020:

- Internet traffic worldwide increased by approximately 30 per cent, with changes in time of day and geographic distribution patterns (including a shift from enterprise to residential access, a portion of traffic shifting from mobile broadband to fixed broadband/Wi-Fi, and sustained traffic levels throughout the day) (Katz, 2020d).
- Telecommunication/ICT capital investment in developed countries accelerated (from 0.5 per cent compound annual growth rate (CAGR) between 2010 and 2019 to 1.8 per cent between 2019 and 2020 in Member States of the Organisation for Economic Co-operation and Development (OECD)) to accommodate the increase in traffic, combined with the deployment of 5G and optical fibre infrastructure.[2]
- Telecommunication/ICT capital investment in developing countries has, however, declined (7.0 per cent between 2019 and 2020 in Latin America, 2.9 per cent in Asia and the Pacific, 3.4 per cent in the Arab States, and 7.0 per cent in Africa), thereby indicating a widening of the digital divide.[3]
- The decline of capital expenditures (CAPEX) per capita in developing countries has resulted in a decreasing growth rate of 4G coverage and lagging deployment of 5G (5G currently reaching 3.34 per cent of the population in Latin America, and 0 per cent of the population in Africa).[4]
- In response to the need to accommodate teleworking, distance learning, remote entertainment and telemedicine, fixed broadband adoption has continued to grow around the world (from 53.3 per cent of households to 58.5 per cent in Latin America, from 53.2 per cent to 55.2 per cent in Asia and the Pacific, from 62.4 per cent to 67.0 per cent in Arab

[1] ITU. The economic contribution of broadband, digitization and ICT regulation and Regional Econometric Modelling. Available at: https://www.itu.int/en/ITU-D/Regulatory-Market/Pages/Economic-Contribution.aspx (all hyperlinks in this document accessed on 4 June 2021).

[2] Analysis by the authors from ITU World Telecommunications/ICT Indicators (WTI) Database 2020 and GSMA Intelligence.

[3] Analysis by the authors from ITU World Telecommunications/ICT Indicators (WTI) Database 2020 and GSMA Intelligence.

[4] Ibid.

States, from 4.5 per cent to 6.0 per cent in Africa, and even from 84.4 per cent to 87.6 per cent in Europe and from 92.0 per cent to 95.5 per cent in North America).[5]

- Broadband prices have continued to fall, which, even in the context of declining incomes, has increased affordability (worldwide fixed broadband prices as a pe<<21-00368_R1_Eco-impact-broadband-digitization-COVID-19_v1-013.eps>><<21-00368_R1_Eco-impact-broadband-digitization-COVID-19_v1-003.eps>>entage of gross national income (GNI) per capita dropped by 3.3 per cent and mobile broadband prices decreased by 5.1 per cent). In the Americas, Asia–Pacific and Arab regions, fixed broadband prices as a percentage of GNI per capita have increased, due to incomes decreasing at a higher rate than prices in the context of the severe economic recession.[6]
- Internet platforms have undergone more intense use, driven by pandemic-induced lockdowns. For example, the use of e-commerce has increased from a worldwide average of 9.5 per cent of total retail trade in 2019 to 12.4 per cent in 2020.[7]

Changes in the ICT ecosystem driven by the disruption of the pandemic (continuing capital spending on infrastructure roll-out in developed countries, jump in broadband penetration, and decline in pricing, especially for mobile broadband) have not substantially altered the importance of ICTs as a driver of economic growth:

- The percentage increment in per capita gross domestic product (GDP), resulting from an increase in 10 per cent broadband penetration worldwide, has remained stable both for fixed (from 0.77 per cent to 0.80 per cent) and mobile broadband (from 1.50 per cent to 1.60 per cent).[8]
- The economic contribution of fixed broadband continues to be greater in developed countries (1.25 per cent increase in GDP per capita as a result of 10 per cent increase in broadband penetration) than in developing countries (0.85 per cent in middle-income countries and non-significant results in low-income countries), reflecting the increasing "returns to scale" effect.[9]
- A similar effect as that of fixed broadband was found using a digitization composite index that captures all dimensions of the digital economy. The impact of digitization in developed economies is higher (1.54 per cent increase in GDP per capita as a result of 10 per cent increase in the index) than in emerging economies (1.00 per cent), again confirming "returns to scale". Digitization was also found to be associated with an increase in labour productivity (1 per cent increase in the digitization index is associated with a 0.25 per cent increase in labour productivity) and total factor productivity (1 per cent increase in the digitization index drives a 0.19 per cent increase in total factor productivity).
- The economic dividend of mobile broadband continues to be greater in countries with lower economic development (2.04 per cent increase in GDP per capita as a result of 10 per cent increase in broadband penetration), diminishing in countries and regions with higher penetration and development (1.62 per cent in middle-income countries and non-significant results in high-income countries), confirming the diminishing returns effect linked to mobile broadband saturation and highly adopted fixed broadband capturing a large portion of the economic contribution.

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5 Analysis by the authors from ITU World Telecommunications/ICT Indicators (WTI) Database 2020, OECD Broadband Portal, and reports from ICT national regulatory authorities.

6 Source: ITU World Telecommunications/ICT Indicators (WTI) Database 2021.

7 Source: Euromonitor (2021).

8 Since the coefficient of impact remains within the 95 per cent margin of error, the increase in economic impact is not statistically significant.

9 In basic economic terms, "returns to scale" describes the quantitative change in output of a firm or industry resulting from a proportionate increase in inputs. If output increases by a greater proportion than the increase in inputs, this is said to present increasing returns to scale. This can occur due to greater efficiency or improved use of fixed costs. The concept is used in this study to describe the non-linear relationship between fixed broadband penetration and economic impact: accordingly, the coefficient of broadband economic contribution countries increases in countries with higher fixed broadband penetration.

- By considering ICT data gathered up to the end of 2020, we found that the economic contributions of mobile broadband in less developed countries, and fixed broadband in middle-income and developed countries were higher than those estimated before the COVID-19 pandemic.

The economic losses of the COVID-19 pandemic during 2020 were not equal for every country affected. When controlling for a range of variables, the countries with better broadband infrastructure were able to mitigate part of the negative economic impact, allowing households, enterprises, and governments to continue functioning.

- In countries with less than 30 per cent fixed broadband household penetration, a 1 per cent increase in COVID-19 induced deceases per 100 population (an indicator of pandemic damage) generated a contraction of GDP per capita of -0.024 per cent. In countries with broadband penetration between 30 per cent and 90 per cent, a 1 per cent increase in deaths per 100 population generated a contraction of GDP per capita of -0.021 per cent: consequently, 15 per cent of the economic damage faced by less-connected economies is mitigated. Likewise, countries with more than 90 per cent broadband penetration have the least elasticity in economic impact, equal to -0.019 per cent: they can mitigate the equivalent of 21 per cent of the economic disruption caused to countries with the lowest connectivity.
- Similarly, in countries with unique mobile broadband subscriber penetration below 50 per cent, an increase of 1 per cent in COVID-19 induced deaths per 100 population generated a contraction of GDP per capita of -0.023 per cent. In countries with penetration levels between 50 per cent and 75 per cent of unique mobile subscribers, an increase of 1 per cent in deaths per 100 population resulted in a contraction of GDP per capita of -0.019 per cent: in other words, 15 per cent of the economic damage faced by less-connected economies is mitigated. For countries with mobile penetration over 75 per cent, the mitigation effect increased to 19 per cent.

The confirmation of the economic contribution of ICTs throughout 2020 and the assessment of the value of broadband in mitigating economic disruption caused by the pandemic provide support for the measures taken so far by policy-makers and regulators to accommodate the resulting changes in sector dynamics. Those measures include:[10]

- granting mobile operators the use of additional spectrum in pre-determined regions of the country;
- temporarily reducing the traffic generated by some video-streaming providers by reducing the definition of video content;
- accelerating the deployment of a large number of base stations for mobile broadband, reducing the permit requirements for the deployment of antennas; and
- address some factors of the digital divide by providing devices (personal computers, tablets, Wi-Fi modems, subsidized broadband services) to vulnerable consumers, and combining this with distance learning training on e-education and telemedicine.

The evidence generated in this study provides additional guidance for some forward-looking actions:

- Policy-makers and regulators in developing countries need to consider initiatives for reversing the declining capital spending trend and stimulating telecommunications investment to ensure continuous roll-out of networks.[11]

[10] ITU Global Network Resiliency Platform (#REG4COVID), https://reg4covid.itu.int/.

[11] ITU (2021). The impact of policies, regulation, and institutions on ICT sector performance. Available at: https://www.itu.int/en/ITU-D/Regulatory-Market/Pages/Economic-Contribution.aspx.

- The importance of ICTs in mitigating some of the pandemic-induced economic damage illustrates the need for policy-makers to reduce demand-side barriers (affordability, digital literacy, local content development) and stimulate the adoption of mobile broadband.
- The high value of fixed broadband as a mitigant of pandemic-induced economic disruption brings to light the urgency with which countries with underdeveloped fixed connectivity need to explore ways to expedite the roll-out of fixed networks, with an initial emphasis on high density urban concentrations.

1. Introduction

A series of studies published by the ITU Telecommunication Development Bureau between 2018 and 2020 (culminating in the publication of a global summary in early 2020 – hereafter, "the 2020 study") examined how broadband and digitization impact the economy, and how institutional and regulatory maturity impact the growth of the digital ecosystem.[1] Supported by econometric models built using data gathered from 139 countries between 2007 and 2018, the studies provided significant evidence on the importance of ICTs as a contributor to economic growth, productivity, and employment. Among the evidence generated through the research, the following seven findings were of critical importance for ICT-related policy-making:

- Mobile broadband generates a larger economic contribution than fixed broadband when examined globally.
- Developing countries benefit more from mobile broadband than industrialized countries.
- Developed countries with high penetration of fixed broadband enjoy greater benefits from the technology than developing countries.
- The economic contribution of digitization, which includes not only the adoption of technology but also its use, is greater in advanced economies than in developing countries.
- Digitization contributes significantly to labour and total factor productivity.
- The development of digitization is driven by institutional and regulatory factors, not only variables such as economic development.[2]
- Digitization accelerates (after an initial time lag) when structural changes related to digital technologies are made in policy and institutions.

Since the publication of the studies referred to above, the outbreak of COVID-19 has raised two critical ICT policy questions:

- Given the changes in the deployment, adoption and use of ICTs since the beginning of the pandemic, has their economic contribution also changed? Econometric models in the 2020 study indicated that ICT has a significant economic impact:
  - A 10 per cent increase in fixed broadband penetration drives 0.77 per cent growth in GDP per capita (higher in developed economies);
  - A 10 per cent increase in mobile broadband penetration yields 1.50 per cent growth in GDP per capita (higher in developing countries);
  - A 1 per cent increase in digitization gives 0.133 per cent growth in GDP per capita.

The structural models used to calculate these coefficients were based on variables that have been subject to major change in the course of 2020 (for example, telecommunication investments,[3] broadband service revenues, and GDP per capita). Are those changes (which may be partially

[1] ITU (2021). The economic contribution of broadband, digitization and ICT regulation and Regional Econometric Modelling. Reports available at: https://www.itu.int/en/ITU-D/Regulatory-Market/Pages/Economic-Contribution.aspx.

[2] ITU (2021). The impact of policies, regulation, and institutions on ICT sector performance. Available at: https://www.itu.int/dms_pub/itu-d/opb/pref/D-PREF-EF.ICT_SECT_PERF-2021-PDF-E.pdf.

[3] While the investment variable is not, strictly speaking, included in the econometric models, it is impacted indirectly by revenues, which is part of the supply equation.

captured in the models' year controls) still affecting the rate of economic impact? Is the impact across geographic areas the same or has it changed?

- **What is the role of ICT infrastructure in increasing countries' economic resilience to the pandemic?** While research into the contribution of ICTs and digitization to mitigating the economic impact of pandemics is limited, evidence of its positive effects is emerging. Based on research into the impact of fixed broadband during the 2003 SARS pandemic (Katz et al, 2020c), one could assume that, in the medium term, countries with top connectivity infrastructure could mitigate some of the negative economic impact of COVID-19. However, there are factors that may limit the capacity of digitization to improve social and economic resilience in the face of the pandemic. First, the digital divide has been highlighted as a critical barrier to the mitigation value of digitization. Second, while large enterprises benefit from access to well-established digital solutions (collaboration tools, employee devices, cloud, VPN) and connectivity, this is not the case for a large portion of small and medium-sized enterprises (SMEs), particularly in developing countries. Datasets compiled up to the end of 2020 should provide a quantitative assessment of the role of ICTs in mitigating the impacts of COVID-19.

The research presented in this report builds on the 2020 study, using the same structure and methodology of econometric models, but examining fixed and mobile broadband, as well as the impact of digitization on the economy up to the end of 2020, and assessing their contribution to increasing social and economic resilience. Chapter 2 provides descriptive statistical evidence of changes that have taken place since 2018, particularly during the pandemic year, in terms of ICT investment, deployment adoption and use. Chapter 3 presents the econometric models and compares the economic impact coefficients of fixed broadband calculated in the 2020 study with the current estimates (hereafter, the new models will be referred to as the "2021 study"). Chapter 4 reviews a similar analysis for mobile broadband. Having completed the comparison between the 2020 and 2021 studies, Chapter 5 provides econometric-based evidence of the capacity of ICTs to mitigate the economic impact of COVID-19. Chapter 6 replicates the 2020 models to assess the economic impact of digitization. Finally, Chapter 7 briefly presents the conclusions and policy implications generated through each analysis. The results of all models are included in the appendices.

2. The evolution of ICTs through the COVID-19 Pandemic: Descriptive statistics

Following the initial wave of fear of contagion and the implementation of first health measures (lockdowns, testing), evidence has emerged suggesting that digital technologies have contributed to counteracting the isolation caused by social distancing measures, increasing awareness of virus prevention measures, and allowing economic systems to continue to operate, at least partially. Overall, Internet traffic worldwide has increased by approximately 30 per cent, with changes to time of day and geographic distribution patterns. The transition to telecommuting has caused a shift from enterprise to residential access. Telecommunications traffic thus no longer comes primarily from central business districts, having shifted instead to residential areas. Similarly, in response to lockdown measures, a portion of data traffic has shifted from mobile to fixed/Wi-Fi networks. Daily Internet traffic patterns have also changed, with morning surges at levels close to the evening peak, partly owing to telecommuting and videoconferencing, but also sustained streaming (Reynolds, 2020). Finally, mobile voice traffic has grown strongly, owing to an increase in both the number of calls and duration of calls.

Along with changes in traffic patterns, COVID-19 has driven changes in ICT investment, deployment and service adoption trends. Positive developments have included:

- **Accelerating telecommunication/ICT capital investment in developed countries**: between 2019 and 2020 telecommunications investment per capita has grown at an average of 3.6 per cent across OECD countries, ranging from 4.7 per cent in North America to 2.2 per cent in the European Union (see Table 1).

Table 1: Change in telecommunication capital investment (in per cent)

Region	CAGR 2010-2019	Delta 2019-2020
OECD	0.5 %	3.6 %
European Union	-0.6 %	2.2 %
Commonwealth of Independent States (CIS)	-5.5 %	3.5 %
Europe	-0.6 %	1.9 %
North America	2.0 %	4.7 %

Source: ITU; GSMA Intelligence, analysis by the authors.

Growth in CAPEX has been propelled by the need to accommodate the traffic increase, combined with the deployment of 5G and optical fibre infrastructure.

- **Continuing growth of fixed broadband adoption around the world**: Adoption of fixed broadband has increased in all continents, albeit at different rates. In response to the need to accommodate teleworking, distance learning, remote entertainment, and telemedicine, fixed broadband has jumped from 53.3 per cent of households to 58.5 per cent in Latin America, from 53.2 per cent to 55.2 per cent in Asia and the Pacific, and from 84.4 per cent to 87.6 per cent in Europe (see Table 2).

Table 2: Growth in fixed broadband connectivity (percentage of households)

Region	2019	2020	Delta
World	54.22 %	56.80 %	4.8 %
Africa	4.34 %	5.96 %	37.4 %
Latin America and the Caribbean	53.32 %	58.54 %	9.8 %
Asia and the Pacific	53.15 %	55.24 %	3.9 %
Arab States	62.39 %	67.04 %	7.4 %
CIS	66.70 %	72.11 %	8.1 %
Europe	84.39 %	87.57 %	3.8 %
North America	92.01 %	95.46 %	3.8 %

Source: 2019 data from ITU,[4] national regulatory authorities (NRAs) and OECD Broadband Portal, compiled by the authors.

- **Lowering of broadband prices:** As well as being driven by the increased need caused by COVID-19, the growth in broadband penetration was enabled by lower service prices. In the context of declining incomes, fixed broadband prices, as a percentage of GNI per capita, declined 3.3 per cent worldwide. That reduction was seen predominantly in Africa, the CIS, and Europe. In other regions, such as the Americas, Asia–Pacific and Arab States, prices as a percentage of GNI per capita increased, due the context of severe economic recession, in which incomes decreased faster than prices. In the case of mobile broadband, the drop in service prices was greater and more generalized at the global level (see Table 3).

4 Data published in: https://www.itu.int/en/ITU-D/Statistics/Documents/facts/FactsFigures2020.pdf and https://www.itu.int/en/ITU-D/Statistics/Pages/stat/default.aspx.

Table 3: Increase in broadband affordability

(service pricing as a percentage of GNI per capita)

Region	Fixed broadband			Mobile broadband		
	2019	2020	Delta	2019	2020	Delta
World	7.39 %	7.14 %	-3.3 %	1.60 %	1.51 %	-5.1 %
Africa	51.61 %	46.08 %	-10.7 %	7.03 %	5.68 %	-19.2 %
Latin America and the Caribbean	3.18 %	3.62 %	13.9 %	1.97 %	1.78 %	-10.0 %
Asia and the Pacific	2.83 %	3.12 %	10.3 %	0.95 %	1.08 %	-13.0 %
Arab States	3.20 %	3.55 %	10.9 %	1.27 %	1.05 %	-17.0 %
CIS	0.88 %	0.77 %	-12.5 %	0.99 %	0.86%	-12.6 %
Europe	1.32 %	1.27 %	-3.7 %	0.60 %	0.61 %	1.6 %
North America	0.86 %	1.00 %	16.3 %	0.44 %	0.43 %	-4.5 %

Source: ITU; analysis by the authors.

- **More intense use of Internet platforms**: as expected, the use of e-commerce has increased from a worldwide average of 9.5 per cent of total retail trade in 2019 to 12.4 per cent in 2020, with the revenue of e-commerce vendors in the Middle East and North Africa jumping 50% from 2019 to 2020 (Redseer Consulting, 2021). In addition, an increase in Internet platform usage was also detected with regard to download of mobile applications by smartphone users: for example, the time spent using apps per day was 4.2 hours, 30 per cent higher than two years previously in India, Mexico, Turkey and the United States. In Brazil, Indonesia and the Republic of Korea it reached five hours (Kristianto, 2021).

Not all trends affecting the evolution of the digital economy have been positive in the last year, however, as shown by the following examples:

- **Declining telecommunication/ICT capital investment in the developing world**: despite the increase in ICT adoption and Internet traffic, CAPEX per capita dropped by 7 per cent in the telecommunication/ICT sector between 2019 and 2020 in Latin America, by 2.9 per cent in Asia and the Pacific, 3.4 per cent in Arab States, and 7.0 per cent in Africa (see Table 4).

Table 4: Telecommunication investment per capita (in USD)

Region	2019	2020	Delta
World	$ 50.86	$50.77	-0.2 %
Africa	$ 9.81	$ 9.12	-7.0 %
Latin America and the Caribbean	$ 45.16	$41.99	-7.0 %
Asia and the Pacific	$ 30.08	$ 29.22	-2.9 %
Arab States	$ 42.54	$ 41.09	-3.4 %
CIS	$ 31.93	$ 33.04	3.5 %
Europe	$ 99.92	$ 101.77	1.9 %
North America	$ 291.50	$ 305.28	4.7 %

Source: ITU; GSMA Intelligence, analysis by the authors.

The decline in CAPEX in developing countries, which can be attributed primarily to the economic recession, is indicative of a widening of the digital divide at precisely the time when the pandemic is driving the need for universal coverage.

- **Slowing 4G network coverage in developing countries**: the decline of CAPEX per capita in developing countries has resulted in a decreasing growth rate of 4G coverage. With 51.7 per cent population coverage in Africa in 2019, 4G deployment only increased to 52.2 per cent in 2020 (0.8 per cent growth from 1.8 per cent in 2018–2019). In the Arab States, 4G coverage increased by 10.5 per cent in 2019-2020, compared with 15.4 per cent in 2018-2019. While coverage in Asia and the Pacific in 2019 was higher than elsewhere (89.6 per cent), roll-out only increased by 0.7 per cent in 2020 (compared with 0.9 per cent in the preceding period). In other words, the population in developing countries unserved by broadband has remained constant, despite the growing need to bridge the digital divide (see Table 5).

Table 5: 4G coverage (by percentage of population)

Region	2018	2019	2020	2018-2019 Delta	2019-2020 Delta
World	84.79 %	85.86 %	86.66 %	1.3 %	0.9 %
Africa	50.80 %	51.72 %	52.16 %	1.8 %	0.8 %
Latin America and the Caribbean	89.25 %	90.09 %	90.46 %	0.9 %	0.4 %
Asia and the Pacific	88.73 %	89.56 %	90.19 %	0.9 %	0.7 %
Arab States	69.18 %	79.80 %	88.17 %	15.4 %	10.5 %
CIS	80.27 %	80.97 %	81.33 %	0.9 %	0.4 %
Europe	90.79 %	91.23 %	92.03 %	0.5 %	0.9 %
North America	97.90 %	97.90 %	97.90 %	0.0 %	0.0 %

Source: GSMA Intelligence, analysis by the authors.

- **Lagging 5G deployment in developing countries**: while 5G coverage by percentage of population in OECD countries increased by 96.8 per cent from 19.95 per cent to 39.26 per cent between 2019 and 2020, Africa has remained without 5G coverage altogether.[5] Latin America only attained 3.34 per cent coverage, and the Asia–Pacific region (which includes OECD countries such as Australia, Japan, New Zealand and the Republic of Korea) has reached only 14.92 per cent. In other words, 5G is a technology that remains prevalent only in the industrialized world (see Table 6).

Table 6: 5G coverage (by percentage of population)

Region	2019	2020	Delta
World	9.10 %	15.96 %	75.3 %
Africa	0.00 %	0.00 %	0.0 %
Latin America and the Caribbean	0.00 %	3.34 %	- - -
Asia and the Pacific	9.64 %	14.92 %	54.9 %
Arab States	7.34 %	15.33 %	108.8 %
CIS	0.00 %	16.61 %	- - -
Europe	12.21 %	24.12 %	97.5 %
North America	35.41 %	63.75 %	80.0 %

Source: GSMA Intelligence; analysis by the authors.

All in all, while worldwide ICT infrastructure, adoption, and use continued to grow over the course of 2020, the divide between developed and developing countries persists.

Given these trends, it is necessary to consider whether the economic contribution of ICTs remains the same as pre-pandemic estimations.

[5] In May 2020, South African mobile network carrier Vodacom launched 5G in Johannesburg, Pretoria and Cape Town. This limited deployment does not, however, have a significant impact on the African continent's overall 5G coverage ratio.

3. The economic impact of fixed broadband through the COVID-19 pandemic

This chapter compares the results of the econometric models published in the 2020 study "How broadband, digitization and ICT regulation impact the global economy", which was based on time series between 2010 and 2018, with the 2021 study, which used the same econometric models but was based on datasets extended to the end of 2020. The purpose is to determine whether ICT externalities remain stable despite the multiple disruptions resulting from the COVID-19 pandemic.

3.1. Fixed broadband and its impact on the economy until 2018

The 2020 study was based on structural models, composed of four equations:

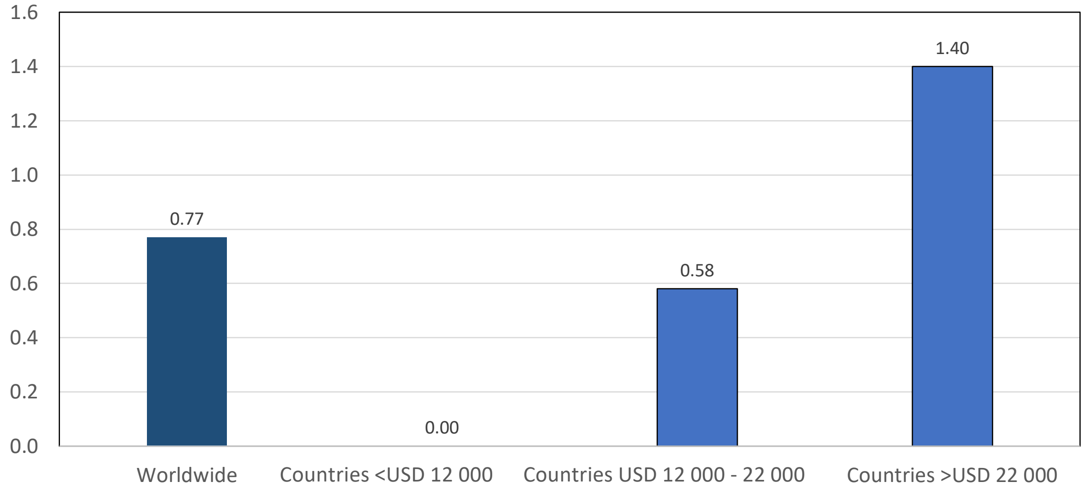
Aggregate production function	$GDP\ per\ capita_{it} = a_1(Capital_{it})+a_2(Education_{it})+ a_3(Broadband\_penetration_{it})+ e_{it}$ (1)
Demand function	$Broadband\_penetration_{it}=b_1(Rural\_population)_{it}+ b_2(Broadband\_price)_{it}+b_3(GDP\ per\ capita)_{it}+b_4(HHI)_{it}+e_{it}$ (2)
Supply function	$Broadband\_revenue_{it}=c_1(Broadband\_price)_{it}+c_2(GDP\ per\ capita)_{it}+ c_3(HHI\ fixed\ broadband)_{it}+ e_{it}$ (3)
Output function	$\Delta\ Broadband\_penetration_{it} = d_1(Fixed\_broadband\_revenue_{it})+ \varepsilon_{4it}$ (4)

In the 2020 study, the authors of this report examined data from 139 countries collected between 2010 and 2017 (in some cases between 2007 and 2018, and for others between 2011 and 2017) and ran the econometric models first for all countries, and subsequently for distinct groups of countries according to their level of development:

- countries with GDP per capita higher than USD 22 000 (50 countries);
- countries with GDP per capita between USD 12 000 and USD 22,000 (26 countries);
- countries with GDP per capita lower than USD 12 000 (63 countries).

The 2020 model results indicated that fixed broadband economic impact tends to increase with economic development (see Figure 1).

Figure 1: 2020 study – GDP growth impact of an increase in 10 per cent of fixed broadband penetration (by economic development)



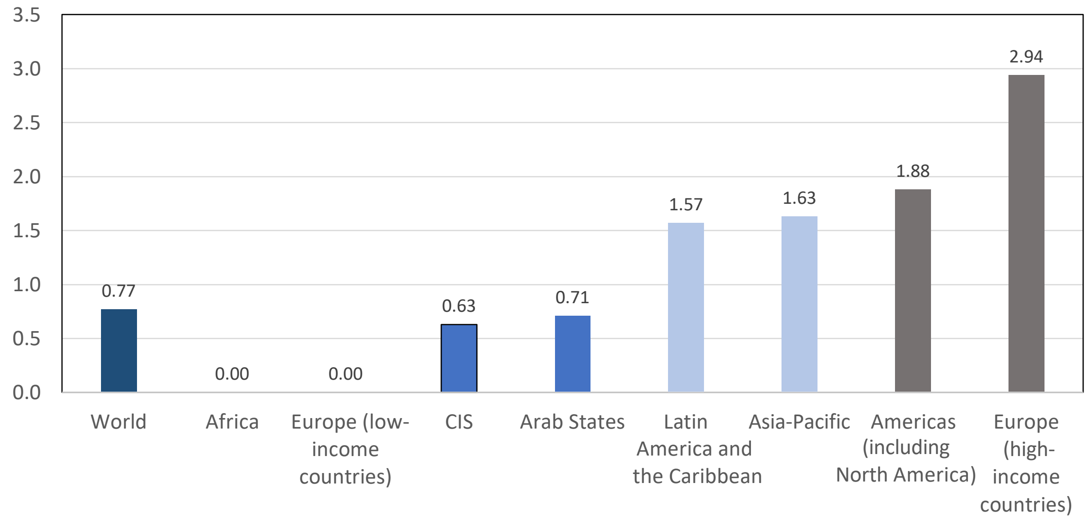
Source: ITU. How broadband, digitization and ICT regulation impact the global economy: Global econometric modelling. November 2020.

The economic impact of fixed broadband was also measured by region:

- Africa (34 countries)
- The Americas (18 countries)
- Arab States (14 countries)
- Asia and the Pacific (18 countries)
- CIS (8 countries)
- Europe (38 countries)

The results by region confirmed that fixed broadband economic impact was higher for developed countries (see Figure 2).

Figure 2: 2020 study – GDP growth impact of an increase in 10 per cent of fixed broadband penetration (by economic development)



Source: ITU. How broadband, digitization and ICT regulation impact the global economy: Global econometric modelling. November 2020.

Identical econometric models were then applied to calculate the impact of fixed broadband for datasets to the end of 2020.

3.2. Fixed broadband and its impact on the economy through the pandemic

The models, run with the whole database (also from 139 countries) with data taken between 2010 and 2020, yielded statistically significant results, which confirmed the results of the 2020 study (see Table 7).

Table 7: 2020 versus 2021 studies–Economic impact of fixed broadband

Variables of fixed broadband model		2020 study	2021 study
	GDP per capita (PPP)		
Fixed broadband subscriber penetration		0.077***	0.080***
Gross fixed capital formation		0.189***	0.109***
Education		0.052***	0.051***
	Fixed broadband subscriber penetration		
Fixed telephone subscribers		0.468***	0.447***
Mobile penetration (†)		/	-0.312***
Rural population		-0.122***	-0.083***
GDP per capita		0.838***	0.882***
Fixed broadband price		-0.301***	-0.416***
HHI fixed broadband		-0.348***	-0.500***
	Fixed broadband revenue		
GDP per capita		1.232***	1.301***
Fixed broadband price		0.188***	0.375***
HHI fixed broadband		-0.775***	-0.869***
	Fixed broadband adoption growth		
Fixed broadband revenue		-0.745***	-0.446***
Observations		3,887	5328
Number of countries		139	139
Country fixed effects		Yes	Yes
Year and quarter fixed effects		Yes	Yes
Years		2010-2017	2010-2020
R-squared		0.995	0.992

***, **, * significant at 1 per cent, 5 per cent and 10 per cent critical value respectively
Note: all variables are expressed in logarithms
(†) To account for a significant fixed mobile substitution, a control for mobile broadband penetration was included in the 2010–2020 model.
Source: ITU; analysis by the authors.

In the context of an increase in broadband penetration, a partial decline in service prices, and a decrease in GDP per capita, the 2010–2020 fixed broadband model indicates that this infrastructure continues to have a significant impact on the world economy. In fact, the coefficient of impact has increased slightly since the 2020 study: with a global dataset extending to the end of 2020, an increase of 10 per cent in fixed broadband penetration yields an increase in 0.80 per cent in GDP per capita. The difference between the two coefficients is, however, within the boundaries of the confidence intervals and therefore cannot be considered statistically significant. Besides, the structural model continues to provide estimates for other important economic parameters. As expected, fixed capital formation continues to be the catalyst for GDP growth, suggesting an important contribution to the economy (0.11 coefficient). Similarly, the educated labour force variable continues to affect economic growth; it is estimated that 1 per cent more skilled labour would increase a country's GDP by 0.05 per cent. The lower coefficient for the capital variable can be attributed both to a limited expansion of infrastructure and significant dependency on quality of the labour force.

Regarding demand for broadband services, prices are the key enablers for uptake of the technology. Strikingly, according to the 2021 study, a 1 per cent drop in prices will boost adoption by more than 0.42 per cent an increase in the coefficient from 0.30 per cent in the 2020 study. This is statistically significant and could indicate that pricing is becoming even more relevant in driving adoption, which would seem plausible once broadband starts to reach a more price-sensitive population.[6] Income variation across the sample period seems to have a similar impact: increasing the average disposable income (proxied by GDP per capita) by 10 per cent yields 8.8 per cent more fixed broadband adoption. This is another confirmation of the relevance of affordability for expanding fixed broadband penetration.

Supply dynamics suggest that, as expected, income levels affect operators' revenues and investments. Consumption propensity for broadband services seems to have a significant impact on increasing the supply of digital offerings. Increasing disposable income (proxied by GDP per capita) by 1 per cent attracts 1.30 per cent more supply in 2021 (an increase from 1.23 per cent in the 2020 study). Finally, fixed broadband operator revenues are found to have a significant impact on the performance of the industry, implying a reinvestment of the output to the productive basis of the economy.[7] This is an additional angle supporting the increasing returns to scale of ICT infrastructure, except that in the 2021 model, the coefficient has declined.

The structural model was also run for selected countries sorted by development level, to test whether fixed broadband economic impact is affected by "returns to scale". As in the 2020 study, the countries in the database were split into three groups:

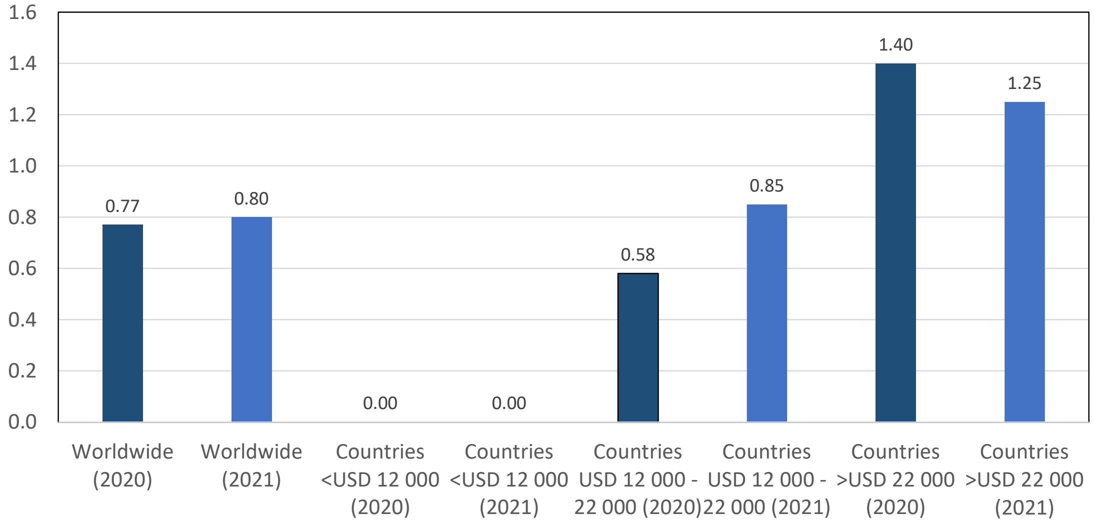
- countries with GDP per capita higher than USD 22 000 (50 countries);
- countries with GDP per capita between USD 12 000 and USD 22 000 (26 countries);
- countries with GDP per capita lower than USD 12 000 (63 countries).

Similar structural models were run for each set of countries, yielding the following results (see Figure 3).

[6] A word of caution: given that this is a structural model based on a system of equations, the results of intermediate equations are inputs for the final result. The coefficients of intermediate steps should not be considered general conclusions. For a model on mobile price elasticity in developing countries, see Katz and Berry (2014).

[7] This is particularly relevant for markets undergoing high growth; it is not the case with saturated markets.

Figure 3: 2020 versus 2021 studies – GDP growth impact of an increase in 10 per cent of fixed broadband penetration (in per cent)



Note: The 2020 study provides evidence of trends over 2010–2017 while the 2021 study is based on 2010–2020 data.

Source: ITU; analysis by the authors.

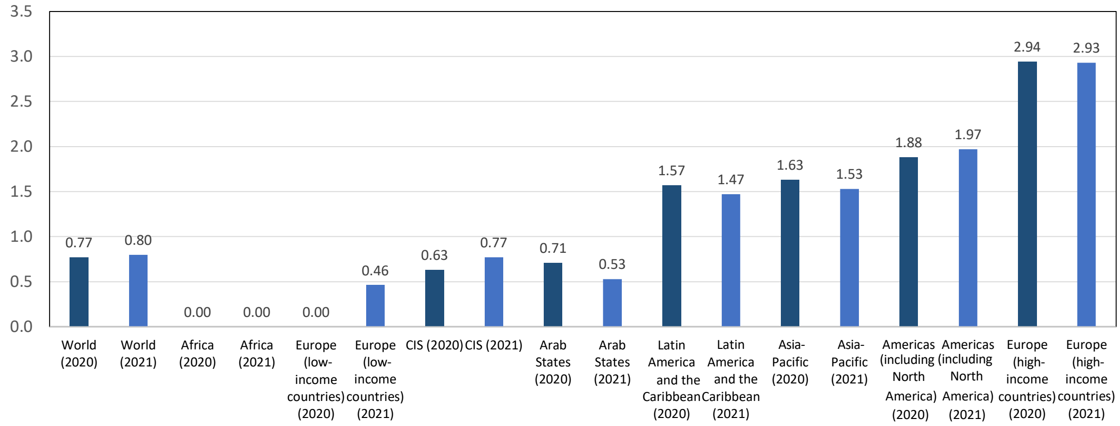
The results of the models run in 2021, using data to the end of 2020, confirmed the effect identified in the 2020 study. Two of the three models indicate a statistically significant positive effect of fixed broadband: countries with GDP per capita higher than USD 22 000 (higher income countries), and countries with GDP per capita between USD 12 000 and USD 22 000.[8] The effect on middle-income countries has increased from a coefficient of 0.58 to 0.85 (although the result is within the 95 per cent margin of error), suggesting returns to scale driven by the rise in fixed broadband penetration in those countries. These findings provide an insight that could be validated by running the model by region (see Figure 4).

The structural model was applied to all regions using the 2010–2020 dataset, assuming an increase of 10 per cent in fixed broadband penetration to calculate any increase in GDP per capita. The models yielded results consistent with those generated in the 2020 study (while the coefficients of impact changed somewhat between the 2020 and the 2021 studies, the values are all within the 95 per cent margin of error).

- Africa: consistent with the results of the prior study, most countries in the region see no economic impact from fixed broadband penetration. This is because adoption of fixed broadband in the region over the past three years has been limited.
- The Americas: "returns to scale", driven by the increase in broadband penetration, mean that countries across this region (North America, Latin America and the Caribbean) would enjoy a GDP increase of 1.97 per cent (compared with 1.88 per cent in the 2020 study).
- Europe: the results of both studies suggest that an increase of 10 per cent in fixed broadband penetration in high-income European countries would yield an increase of around 2.94 per cent in GDP per capita. However, contrary to calculations in the 2020 study, where the coefficient for low-income European countries was statistically not significant, in 2021 those

[8] As in the 2020 study, to address the model limitations for middle-income countries, we reduced the dataset to start in the third quarter of 2013 up to the fourth quarter of 2017, following the logic that prior to 2013, fixed broadband penetration was low and economic effects were therefore negligible.

Figure 4: 2020 versus 2021 studies – Regional GDP growth impact of an increase in 10 per cent of fixed broadband penetration (in per cent)



Source: ITU; analysis by the authors.

countries would enjoy an increase of 0.46 per cent in GDP per capita. This reconfirms the "returns to scale" driven by higher broadband penetration.

- CIS: by applying the model to the 2010–2020 dataset, the estimated increase in GDP per capita in the region is 0.77 per cent (compared with 0.63 per cent in the 2020 study).
- Two regions –the Arab States and Asia and the Pacific – do not exhibit a GDP per capita increase coefficient based on the 2010–2020 dataset, although, as mentioned above, the values are all within the 95 per cent margin of error. One could speculate that both regions represent an aggregation of a heterogeneous group of countries with divergent development levels, where the economic contribution of broadband varies widely within each group.

In summary, the comparison between the results of the structural model, when run against the 2010–2018 and 2010–2020 fixed broadband datasets, yields three conclusions.

1. Due to an increase in broadband penetration, and a partial decline in service prices in 2020, the coefficient of economic impact of fixed broadband has remained stable since the 2020 study. This is despite the decline in GDP per capita that resulted from the COVID-19-induced recession.
2. Suggesting a "returns to scale" effect, the increase in fixed broadband penetration in the Americas, Europe and CIS, has resulted in a slightly higher coefficient of GDP per capita, resulting from a 10 per cent rise in broadband penetration. More research will be needed, however, to confirm this trend as in some cases the current differences are within the boundaries of the confidence interval.
3. Given that there has not been a significant increase in fixed broadband penetration in the African region since 2018, there has been no change to the economic contribution of this technology.

4. Mobile broadband and its impact on the economy through the COVID-19 pandemic

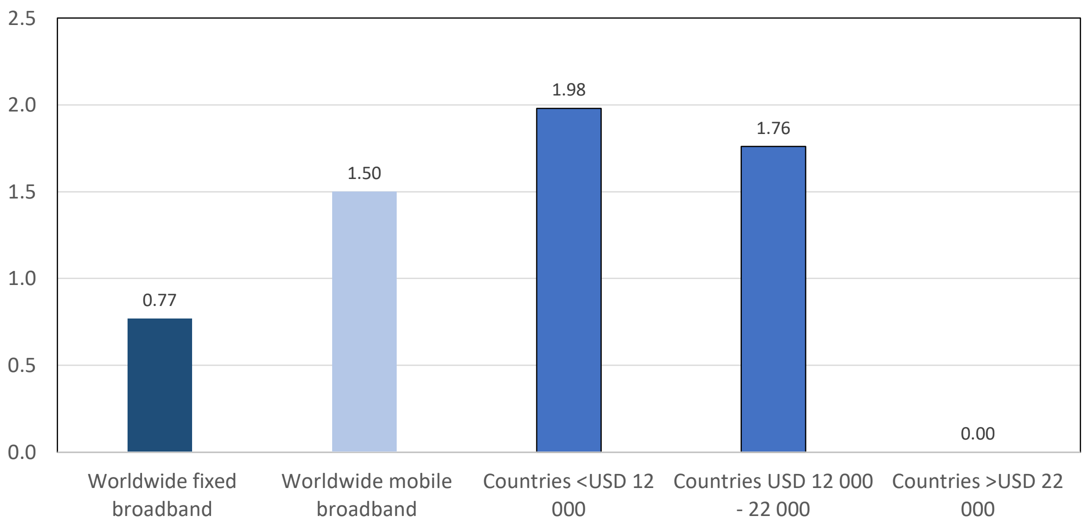
The 2020 study concluded that in countries with low fixed broadband penetration (those that have low GDP per capita), mobile broadband technology becomes the pre-eminent technology driving economic growth. This was confirmed by running the structural model for mobile connectivity with datasets up to the end of 2020.

The purpose of this chapter is to compare the results of the 2020 study econometric models with similar models based on datasets extended to the end of 2020. As mentioned above, the purpose is to determine whether the externalities of ICT remained stable, despite the multiple disruptions resulting from the pandemic.

4.1. Mobile broadband and its impact on the economy up to 2018

Previous studies of mobile broadband impact were based on structural models similar to those used to measure the contribution of fixed broadband. The models were run for 139 countries between 2010 and 2017 for the global sample, and also for countries differentiated by level of development. The models were also run by aggregating countries by region. The results of the 2020 study indicated that, in the aggregate, mobile broadband economic contribution is higher than that of fixed broadband, although the impact decreases with economic development (see Figure 5).

Figure 5: 2020 Study – GDP growth impact of an increase in 10 per cent of mobile broadband penetration (by economic development)



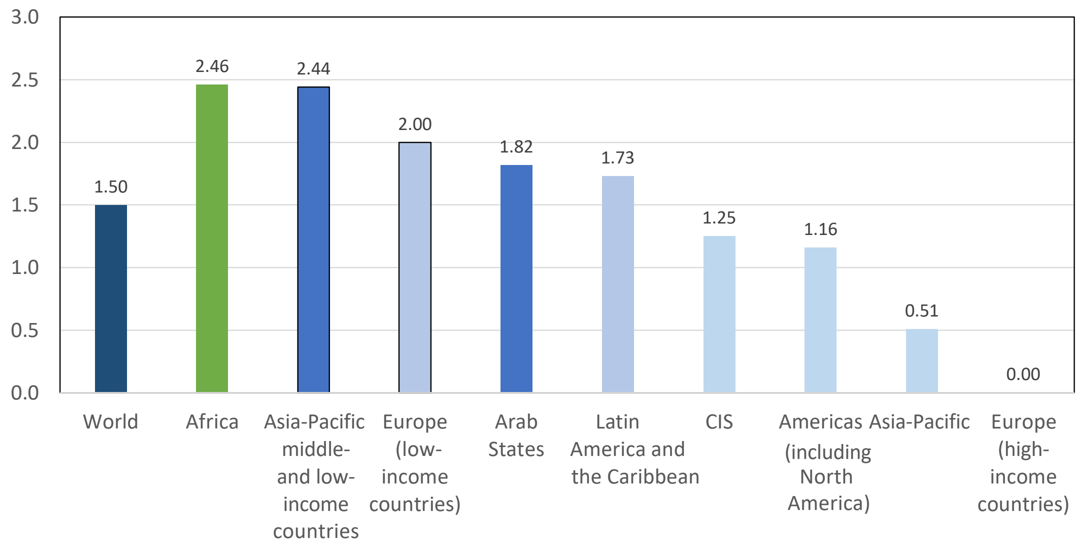
Source: ITU. How broadband, digitization and ICT regulation impact the global economy: Global econometric modelling. November 2020.

The models were also run to measure the economic impact of mobile broadband by region:

- Africa (34 countries)
- The Americas (18 countries)
- Arab States (14 countries)
- Asia and the Pacific (18 countries)
- CIS (8 countries)
- Europe (38 countries).

The results by region indicated that developing countries receive greater economic benefit from mobile broadband than advanced economies (see Figure 6).

Figure 6: 2020 study – GDP growth impact of an increase in 10 per cent of mobile broadband penetration (by economic development)



Source: ITU. How broadband, digitization and ICT regulation impact the global economy: Global econometric modelling. November 2020.

The same models were applied to calculate the impact of fixed broadband for datasets from 2010 to the end of 2020, to assess the impact through the pandemic.

4.2. Mobile broadband and its impact on the economy through the pandemic

The models, run with the whole database (for 129 countries) with data from 2010 to 2020, yielded statistically significant results, confirming the results published in the 2020 study (see Table 8).

Table 8: 2020 and 2021 studies – Economic impact of mobile broadband

Variables of mobile broadband model	2020 study	2021 study
GDP per capita (PPP)		
Mobile broadband subscriber penetration	0.150***	0.160***
Gross fixed capital formation	0.215***	0.137***
Education	0.056***	0.048***
Mobile broadband subscriber penetration		
Mobile penetration	1.680***	1.694***
Rural population	-0.036***	-0.052***
GDP per capita	0.060***	0.046***
Mobile broadband price	0.007	-0.012
HHI mobile broadband	-0.371***	-0.331***
Mobile broadband revenue		
GDP per capita	0.088***	0.517***
Mobile broadband price	0.110***	0.129***
HHI mobile broadband	-2.120***	-1.547***
Mobile broadband adoption growth		
Mobile broadband revenue	-1.142***	-0.008***
Observations	3,858	5,227
Number of countries	139	129
Country fixed effects	Yes	Yes
Year and quarter fixed effects	Yes	Yes
Years	2010–2017	2010–2020
GDP per capita (PPP)	All	All
R-squared	0.998	0.993

***, **, * significant at 1%, 5% and 10% critical value respectively
Note: All variables are expressed in logarithms.
Source: ITU; analysis by the authors.

In the context of an increase in mobile broadband penetration, a generalized decline in service prices, and a decrease in GDP per capita, the 2010–2020 mobile broadband model used in the 2021 study shows that mobile infrastructure continues to have a stable impact on the world economy. The coefficient of impact has remained constant since the 2020 study; with a dataset extended to the end of 2020, an increase of 1 per cent in mobile broadband penetration yields an increase in 0.16 per cent in GDP. Furthermore, the structural model provides estimates for other important parameters of the economy. Fixed capital formation has declined as a catalyst for GDP growth, reducing its coefficient from 0.21 per cent to 0.14 per cent, which could, in part, be a consequence of the COVID-induced recession.[9] There is a similar effect with respect to the educated labour force contribution to economic growth: it is estimated that 1 per cent more skilled labour would increase a country's GDP by 0.05 per cent.

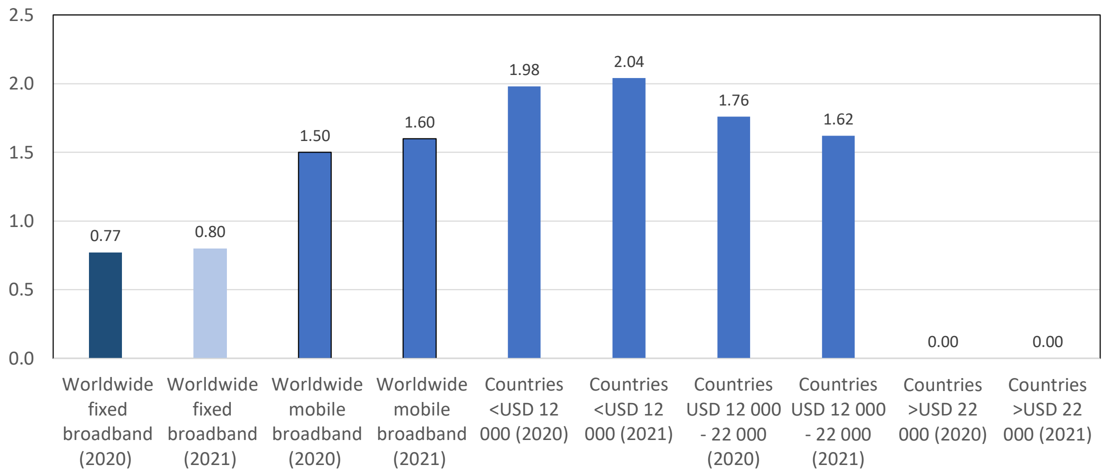
Contrary to fixed broadband, mobile broadband service pricing is not statistically significant in driving adoption. However, income variation across the sample period seems to have a slightly smaller impact on adoption. Increasing average disposable income (proxied by GDP) by 10 per cent thus yields 0.5 per cent more mobile broadband adoption. This confirms the relevance of affordability to mobile broadband penetration, although it also shows that at higher levels of adoption, income elasticity does not seem to be a major factor driving penetration.

The structural model was also run with 2010–2020 data to test whether the economic impact of mobile broadband is affected by a "returns to scale"or a "diminishing returns" effect. As in the prior studies, the database was split into three groups of countries:

- countries with GDP per capita higher than USD 22 000 (50 countries);
- countries with GDP per capita between USD 12 000 and USD 22 000 (26 countries);
- countries with GDP per capita lower than USD 12 000 (63 countries).

Similar structural models were run for each set of countries, yielding the following results (see Figure 7).

Figure 7: 2020 versus 2021 studies – GDP growth impact of an increase in 10 per cent of mobile broadband penetration (in per cent)



Source: ITU; analysis by the authors.

The results of the models run with data to the end of 2020 confirmed the effect previously identified in the 2020 study.

First, the impact on GDP per capita is higher for mobile broadband than for fixed broadband.

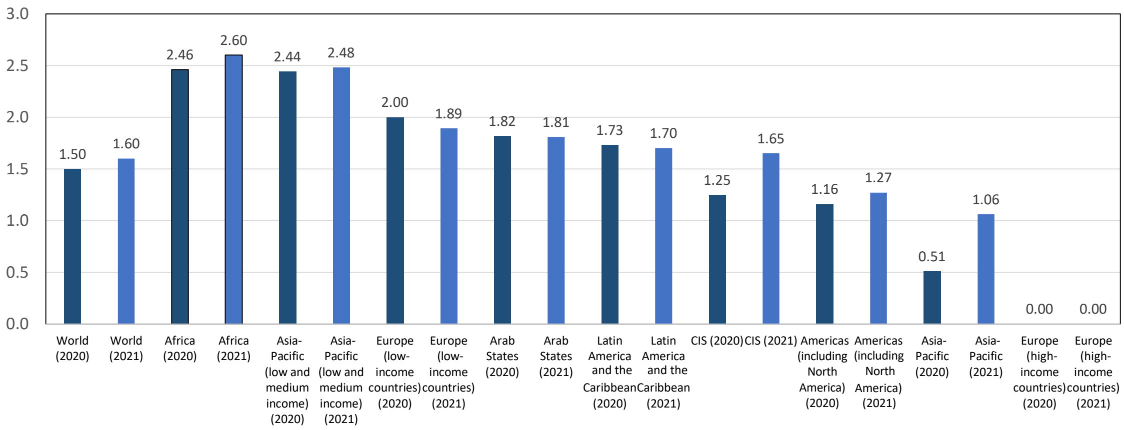
[9] Gross fixed capital formation, a measure of net investment, is generally subject to a decline during periods of recession.

Second, two of the three models indicate a statistically significant positive effect of fixed broadband: countries with GDP per capita lower than USD 12 000 (lower-income countries), and countries with GDP per capita between USD 12 000 and USD 22 000.[10]

Third, confirming the "diminishing returns" effect for highly developed countries, the coefficient of economic impact for countries with GDP per capita higher than USD 22 000 (higher-income countries) is not statistically significant.

Fourth, the results of the 2021 study models are consistent with those of the 2020 study. These findings provide an insight that could be validated by running the model by region (see Figure 8).

Figure 8: 2020 versus 2021 studies – Regional GDP growth impact of an increase in 10 per cent of mobile broadband penetration (in per cent)



Source: ITU; analysis by the authors.

Econometric modelling was applied to all regions using the 2010–2020 dataset, assuming an increase of 10 per cent in mobile broadband penetration to calculate increase (or not) in GDP per capita, the models suggested the following results, presented in comparison with those generated in the 2020 study (while the coefficients of impact changed somewhat between the 2020 and 2021 studies, the values are all within the 95 per cent confidence interval):

- Europe (high-income countries): consistent with the "diminishing returns" effect due to saturation, the impact on GDP per capita derived from mobile broadband penetration is not statistically significant.
- Europe (low-income countries): in this group of countries, the coefficient of economic impact decreased from 2.00 per cent to 1.89 per cent, although this decline is within the 95 per cent confidence interval.
- The Americas: driven by the "diminishing returns" resulting from saturation, countries across North America, Latin America and the Caribbean would enjoy a GDP increase of 1.27 per cent (compared with 1.16 per cent in 2018). When isolated from the rest of the region, the coefficient of impact on GDP per capita for Latin America remains constant, at around 1.70 per cent.
- Asia and the Pacific: all countries in this region would enjoy an increase of 1.06 per cent in GDP per capita, representing an increase from 0.51 per cent in 2018.

[10] As in the 2020 study, to address the model limitations for middle-income countries, we reduced the dataset to start at third quarter of 2013 and end at the fourth quarter of 2017 following the logic that before 2013, fixed broadband penetration was low and therefore economic effects were negligible.

- Asia and the Pacific (low- and middle-income countries): as in Africa, the coefficient of GDP impact increased, albeit at a lower rate and, as stated above, consistent with the 95 per cent confidence interval: from 2.44 per cent to 2.48 per cent.
- Africa: consistent with the results in the 2020 study, most countries in the region would enjoy a significant increase in GDP. The coefficient of 2.60 per cent increased from 2.46 per cent in the 2020 study suggesting an incremental return to additional mobile broadband penetration.
- Arab States: countries in this group would enjoy an increase in 1.81 per cent in GDP per capita, consistent with the 2020 study.
- CIS: the countries in this region would enjoy an increase of 1.65 per cent, a jump from 1.25 per cent in the 2020 study, although again that result is within the 95 per cent confidence interval.

The comparison between the results of the structural model run against the 2010–2018 and 2010–2020 mobile broadband datasets yields the conclusions below.

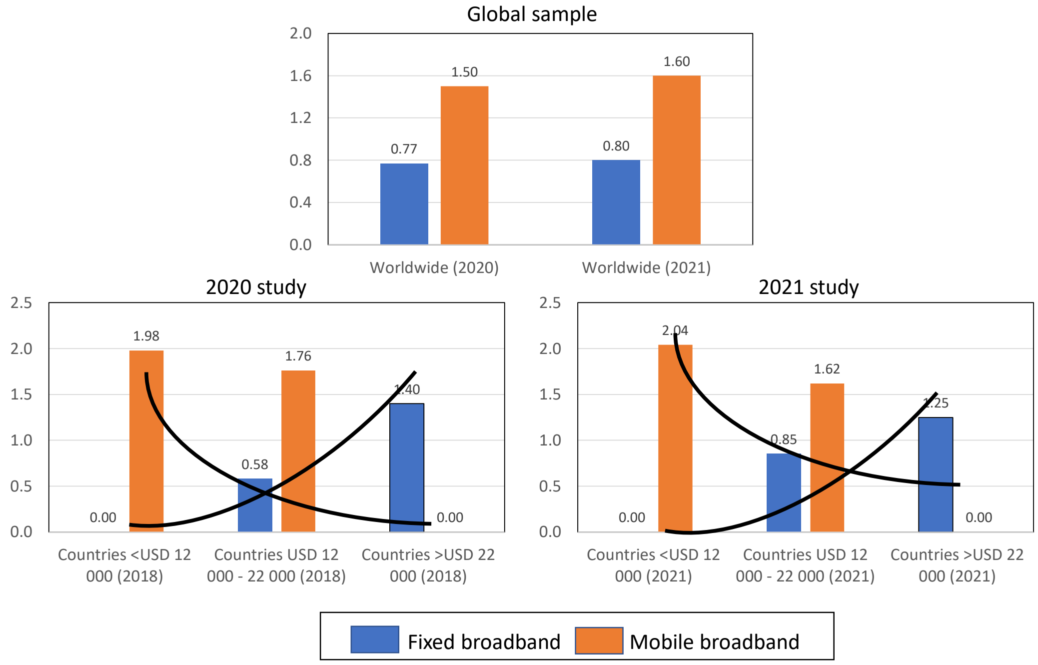
- First, in the context of an increase in mobile broadband penetration and a partial decline in service prices, the coefficient of economic impact of mobile broadband has remained stable since the 2020 study. Some regions (Africa, the Americas, Asia–Pacific and CIS) might have undergone an increase in mobile broadband's economic impact. This has occurred despite the decline in the GDP per capita that resulted from the COVID-19 induced recession. However, future research will be needed to confirm this trend as the current differences lie within the boundaries of the condidence intervals.
- Second, suggesting a "diminishing returns" effect, the increase in mobile broadband penetration in low-income European countries might have yielded a decline in the economic impact coefficient. Similarly, given the high mobile broadband penetration in high-income countries in Europe, the technology's economic contribution is not statistically significant.

5. Global analysis of fixed and mobile broadband and its impact on the economy through the COVID-19 pandemic

In summary, by running the structural models for the dataset ending in 2020 for fixed and mobile broadband, the conclusions below can be drawn.

- The changes in the broadband ecosystem in many countries, which came in response to the disruption caused by the pandemic (continuing capital spending in roll-out, jump in penetration, decline in pricing, especially in mobile) have not substantially altered the conclusions drawn in the 2020 study.
- That having been said, in the global sample, the percentage increase in per capita GDP resulting from a 10 per cent increase in broadband penetration has increased slightly, both for fixed and for mobile broadband, although as previously stated, the values are all within the 95 per cent confidence interval.
- The contribution of fixed broadband continues to be greater in developed countries than in developing countries, reflecting the "returns to scale" effect.
- The economic dividend of mobile broadband continues to be greater in countries with lower levels of economic development, diminishing in countries and regions with higher penetration and development.
- In comparison with the previous study results, by considering a dataset extended to the end of 2020 we identified a higher economic contribution of mobile broadband in low-income developed countries and of fixed broadband in middle-income developed countries.

Figure 9: 2020 versus 2021 studies – GDP growth impact of a 10 per cent increase in broadband penetration (in per cent)



Source: ITU; analysis by the authors.

6. The contribution of ICTs to increasing economic resilience in the context of the COVID-19 pandemic

The COVID-19 pandemic constitutes a fundamental challenge for the global socioeconomic system, forcing countries to re-examine social practices and production systems that until 2020 were considered normal. Massive social distancing measures have been taken, including severe lockdowns and abrupt falls in travelling and tourism. Over the course of 2020, the global economy went into recession, contracting by -3.3 per cent according to the most recent data provided by the International Monetary Fund (IMF, 2021). A strong recovery is expected in 2021, however.

Following the strict lockdowns imposed in several countries since the first quarter of 2020, strong evidence has emerged suggesting that digital technologies contribute to counteracting those isolation measures, allowing economic systems to continue operating, at least partially. This chapter investigates the extent to which digital infrastructure (more specifically, fixed, and mobile broadband) has mitigated the negative economic impact of the COVID-19 crisis. As explained in the introduction to this report, the underlying hypothesis is that beyond the economic contribution of ICTs under normal conditions (addressed in the previous chapters), ICTs can also be essential in building economic resilience in health emergency situations, such as the COVID-19 pandemic.

In addition to measuring the overall economic impact of ICTs, this chapter looks at the use of econometric models for testing the importance of ICTs in mitigating the economic disruption caused by the pandemic. The analyses presented in this chapter provide empirical evidence, using the latest data from 2020, in which most economic indicators were affected by the COVID-19 pandemic.

6.1. Study hypothesis

As stated above, further to the positive economic impacts on GDP, employment and productivity, broadband technology can also be essential for providing economic resilience in emergency situations, such as forced lockdowns. At the household level, broadband allows citizens to carry out many daily tasks that previously required physical contact. Examples of this are the possibility of accessing health apps (e-health), buying products online (e-commerce), studying using virtual tools and platforms (e-education) and teleworking.[11] At the enterprise level, digitization of production is critical in keeping the economy running in the event of disruption. Beyond giving workers the possibility to telecommute, digitized supply chains and distribution channels can

[11] Of course, this implies that simply being connected is not enough: the way individuals use the Internet may hinder their ability to offset the economic damage. For instance, as explained in other research (Katz et al, 2020a), in most developing countries Internet is typically used primarily to communicate and access social networks, rather than for more sophisticated uses that are key to the above-mentioned resilience.

substantially contribute to keeping production active in situations where face-to-face interaction with customers and suppliers must be avoided. Finally, broadband and digitization can increase resilience at the government level, by allowing public institutions to continue their operations and deliver public services.[12]

Thus far, empirical evidence on the role of digitization in mitigating the economic losses resulting from emergency conditions is scarce and refers mainly to natural disasters, with a focus on digitization for providing information for decision-making (Teodorescu, 2014), or for allowing critical services to continue operating (O'Reilly et al, 2006). In the specific case of pandemics, Chamola et al (2020) highlights the use of technologies, such as the Internet of Things (IoT), unmanned aerial vehicles (UAVs), blockchain, artificial intelligence (AI), and 5G, among others, to help mitigate the effects of those outbreaks, although their economic impacts are not quantified. More recently, the authors of this study provided empirical evidence that the economic losses of the 2003 SARS outbreak were not equal for all countries affected (Katz et al, 2020b). Rather, when controlling for a range of variables, the countries with better broadband infrastructure were able to counteract part of the negative economic impact, allowing households, enterprises and governments to continue functioning. Their results showed that countries with 10 per cent fixed broadband penetration underwent a decline in GDP of -0.045 per cent for every 1 per cent increase in infections in the population. Conversely, countries with more than 20 per cent fixed broadband penetration incurred a negligible GDP contraction for every 1 per cent increase in infections.

Given the above, it seems clear that we can expect more digitized societies to exhibit higher economic resilience in the case of a pandemic disruption. More specifically:

The economic losses of the COVID-19 pandemic over the course of 2020 were not equal for every country affected. Rather, when controlling for a range of variables, the countries with better broadband infrastructure were able to counter part of the negative economic impact, allowing households, enterprises, and governments to continue functioning.

6.2. Empirical specification

We began by reformulating the first equation of the structural model presented in Chapter 3, linking GDP per capita with gross fixed capital formation (GFKF), human capital (HK) and broadband penetration (BB PEN). To consider the 2020 disruption, we add, as a control variable, an indicator for the degree of spread of COVID-19, with the assumption that the higher the rates of infection, the broader and stricter the isolation measures, which will result in more significant economic damage. It is important to consider the possibility of measurement errors in the control variables linked to the pandemic, which could cause endogeneity in the estimation.[13] To control for these concerns and ensure unbiased results, several measures were taken.

[12] Beyond the services that are less impacted by digitization (e.g. public health and safety), it is clear that a digitalized government has greater capacity to continue providing public services without interruption.

[13] Measurement errors can arise as some countries may use different criteria for calculating COVID cases, while, countries with weak institutions or authoritarian regimes may intentionally manipulate their numbers. In addition, countries differ in their approaches to testing, resulting in larger infected ratios for those that carry out mass testing. Finally, different countries have followed different health-care strategies to deal with the pandemic.

First, to measure COVID prevalence in each country, we use as the reference indicator the quantity of COVID-attributed deaths for every 100 inhabitants, according to data from John Hopkins University.[14] This variable is more reliable than, for instance, the rate of infection, which is more prone to reflecting differences in testing strategies.

Second, a panel analysis allows for controlling for fixed effects. If the country characteristics related to measurement differences are time-invariant, these differences will be absorbed by the fixed effects. As highlighted by Bound and Krueger (1991), when measurement errors are explained by factors consistently repeated over time, first-differencing (as performed by the fixed-effects estimate) can conceivably increase the reliability of the data. The fixed-effects approach will not, however, resolve problems generated by measurement error, if these are serially uncorrelated over time. More specifically, if government behaviour during the pandemic differs from its past patterns, the fixed effects will not be able to absorb these differences. Thus, we include a specific dummy variable for each country in 2020 to absorb the effects that explain the different approaches followed by countries with regard to reporting or testing.

Third, to account for the role of digitization in counteracting the economic impact of the pandemic, we add an interaction variable between broadband connectivity and COVID diffusion in squares, as this specification has proven to provide the better fit to our model.

The first equation of the structural model is represented as:

$$Log\left(GDPpc\right)_i = \mu_i + \theta Log\left(GFKF\right)_{it} + \sigma Log\left(HK\right)_{it} + \beta Log\left(BB\,PEN\right)_{it} + \delta COVID_{it}$$
$$+ \Upsilon\left(BB{*}COVID^2\right)_{it} + \rho_{i,2020} + \zeta_t + \varepsilon_{it}$$

Where:

- μ_i accounts for country-level fixed effects
- $\rho_{i,2020}$ is a specific effect for each country during 2020
- ζ_t reflects the controls for time period (year and quarters).

In this equation, we expect the parameter associated to COVID to present a negative sign, given that the larger the incidence of the disease, the worse the economic outcome, so $\delta < 0$. In addition, as our main hypothesis stipulates that societies that are more connected were better able to mitigate part of the economic damage of the pandemic, the parameter associated with the interaction variable is expected to be positive, $\Upsilon > 0$.

To measure how COVID affects economic output, we must differentiate the previous equation with respect to COVID. Therefore, and subtracting the subindices for simplicity, we obtain:

$$\frac{\partial Log\left(GDPpc\right)}{\partial COVID} = \delta + 2\Upsilon\left(BB{*}COVID\right)$$

Considering that $\partial Log\left(GDPpc\right) = \partial\left(GDPpc\right)/\left(GDPpc\right)$, and multiplying both sides of the equation by the COVID variable, we can derive an expression of the elasticity between deaths per 100 population and GDP per capita:

14 https://coronavirus.jhu.edu/map.html.

$$\varepsilon_{(GDP\,pc,\,COVID)} = \frac{\partial GDPpc}{\partial COVID}\frac{COVID}{GDPpc} = \left(\delta + 2\Upsilon\left(BB^{*}COVID\right)\right)^{*}COVID$$

The elasticity will be negative as long as $\delta + 2\Upsilon\left(BB * COVID\right) < 0.$ On the assumption that $\delta < 0$ and $\Upsilon > 0$, it seems clear that countries with high connectivity (measured by BB) will present a lower elasticity (in absolute terms). In other words, better connected countries are expected to experience lower economic damages.

6.3. Econometric model results

The first equation is introduced within the framework of the four-equation structural model reviewed in Chapter 3, and has been tested empirically both for fixed and for mobile broadband.

6.3.1. Impact of fixed broadband in mitigating COVID 19-induced economic disruption

Given that the link between broadband penetration and economic mitigation was found not to be necessarily linear,[15] we proceeded to use dummy connectivity variables for the interaction term with COVID, rather than the continuous broadband series.[16] For fixed broadband adoption, we identify three relevant thresholds: 10 per cent, 30 per cent and 90 per cent household penetration levels. The first is useful to classify unconnected countries: all economies with penetration below 10 per cent are assumed not to meet the conditions for fixed broadband to contribute to mitigating the economic impacts of the pandemic. The second threshold, 30 per cent, represents a minimum percentage of connectivity required for the country to successfully undertake a migration to telecommuting and ensure the functioning of supply chains.[17] Finally, the 90 per cent threshold was used to account for fully digitalized countries that have incorporated the latest digital technologies in their production processes, especially supply chains. Dummy variables were assigned to each country according to their fixed broadband penetration (see Table 9).

[15] This means that the mitigating effect could accelerate or diminish with broadband, according to some service penetration thresholds.

[16] An interaction variable is constructed from an original set of variables to try to represent either all or part of the interaction present. An interaction may arise when considering the relationship between three or more variables, and describes a situation in which the effect of one causal variable on an outcome depends on the state of a second causal variable (that is, when effects of the two causes are not additive).

[17] As a reference, an analysis performed by these authors for Chile found that, during the early 2020 lockdown, 29 per cent of workers forced to remain under home isolation could continue to work remotely (Katz et al, 2019).

Table 9: Thresholds defined for fixed broadband (FBB) household penetration to be considered in interaction with the COVID effect

Indicator	Description	Examples
FBB penetration < 10%	Unconnected countries, expected to face the worst economic outcomes from the crisis.	Afghanistan, Cameroon, Zimbabwe
FBB penetration 10%-30%	Low-connected countries. While a certain percentage of households and enterprises are connected, this is expected to be insufficient to ensure continued economic activity during lockdowns.	Indonesia, Namibia, Paraguay,
FBB penetration 30%-90%	Connected countries. By surpassing the 30 per cent threshold, it is assumed that these countries are able to ensure mass migration to teleworking, while keeping supply chains running.	Brazil, Croatia,
FBB penetration > 90%	Fully connected countries. These countries are expected to experience a complete process automatization and are believed to be the least affected by lockdowns.	Germany, United Kingdom, United States

Source: Authors

Having assigned the dummy variables to each country according to broadband penetration, the model was run. Table 10 summarizes the econometric results for the structural model for fixed broadband.

Table 10: Estimate of the fixed broadband structural model

Log (GDP per capita)	
Log (Gross fixed capital formation)	0.115***
	[0.010]
Log (Human capital)	0.047***
	[0.011]
Log (Fixed broadband penetration)	0.100***
	[0.013]
COVID (deaths/100 inhabitants)	-0.282***
	[0.079]
(FBB penetration 10%-30%)*COVID[2]	-0.051
	[1.205]
(FBB penetration 30%-90%)*COVID[2]	0.241**
	[0.093]
(FBB penetration > 90%)*COVID[2]	0.342**
	[0.146]

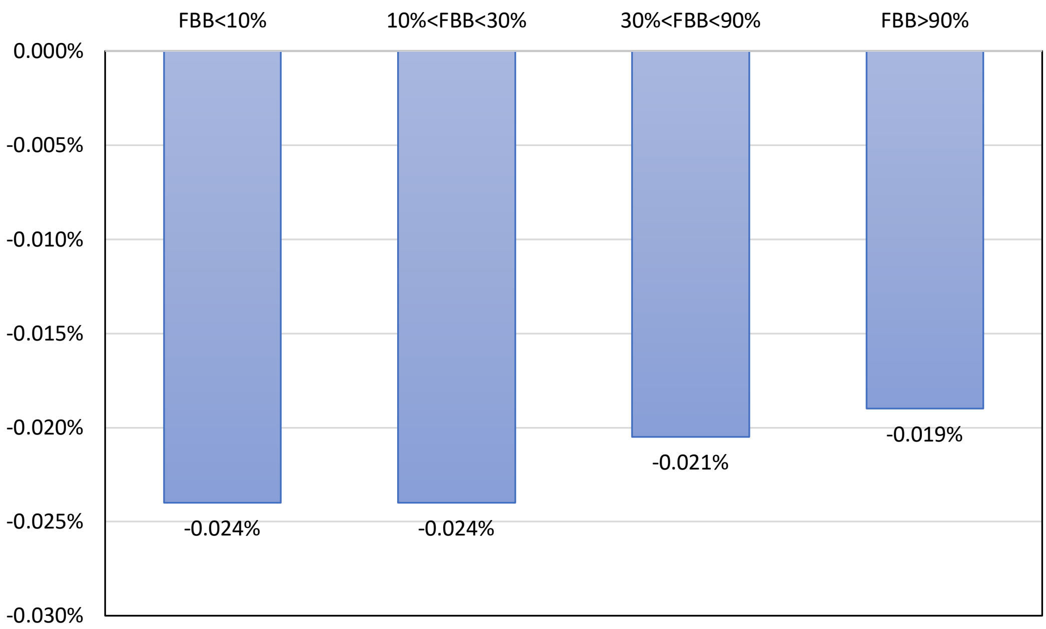
Table 10: Estimate of the fixed broadband structural model (continued)

Log (Fixed broadband penetration)	
Log (Fixed telephone penetration)	0.447***
	[0.013]
Log (Mobile penetration)	-0.313***
	[0.008]
Log (Rural population)	-0.084***
	[0.021]
Log (GDP per capita)	0.882***
	[0.021]
Log (fixed broadband price)	-0.416***
	[0.012]
Log (HHI fixed broadband)	-0.502***
	[0.018]
Log (Fixed broadband revenue)	
Log (GDP per capita)	1.299***
	[0.022]
Log (Fixed broadband price)	0.374***
	[0.021]
Log (HHI fixed broadband)	-0.872***
	[0.032]
Log (Broadband adoption growth)	
Log (Fixed broadband revenue)	-0.438***
	[0.043]
Observations	5326
Country fixed effects	Yes
Year and quarter fixed effects	Yes
R-squared (first equation)	0.993

Note: standard errors in parentheses. *p<10%, **p<5%, ***p<1%
Source: ITU; analysis by the authors.

As expected, the COVID variable has a negative sign and is significant at a 1 per cent level, highlighting the damage caused by the pandemic to national economies. The interaction variables exhibit the expected results: non-significant for the 10–30 per cent interval, which seems to confirm our hypothesis that fixed broadband connectivity below 30 per cent is not enough to ensure a mass migration to teleworking, therefore limiting the possibilities of cushioning the economic contraction. On the other hand, countries that surpass the 30 per cent fixed broadband penetration level were able to mitigate some economic damage, as the interaction term for these economies (FBB penetration 30%–90 %) * COVID) is positive and significant.[18] Finally, fully connected economies (fixed broadband penetration above 90 per cent) were able to achieve higher levels of damage limitation through digitization. Following these results, elasticities were calculated assuming a level of COVID deaths per 100 population similar to the mean of the sample in 2020 to estimate the economic impact of COVID-19 as a function of broadband penetration (see Figure 10).

Figure 10: Percentage variation in quarterly GDP per capita after an increase of 1 per cent in COVID deaths per 100 population – by level of fixed broadband penetration



Source: ITU; analysis by the authors.

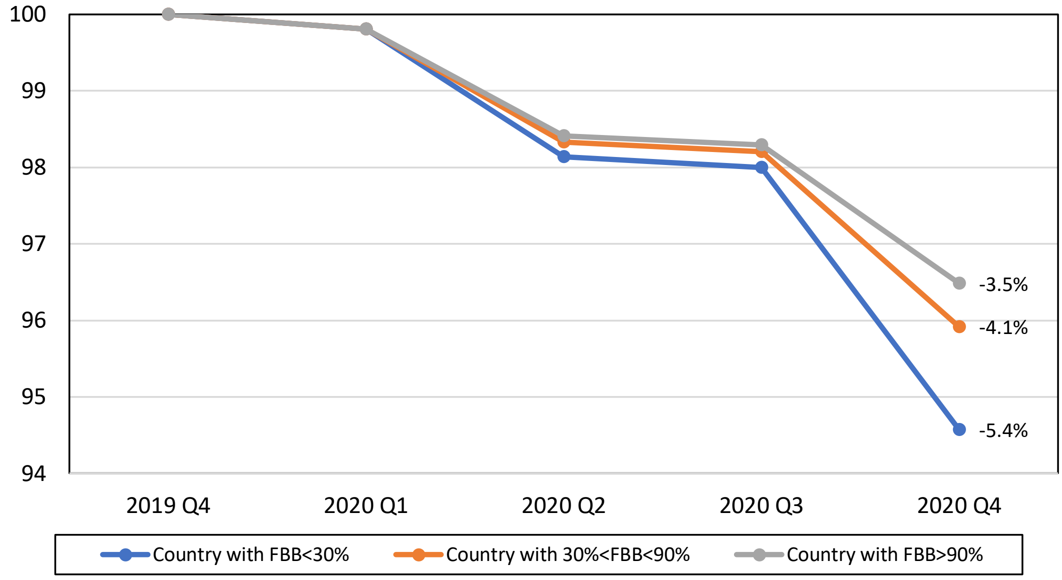
According to the values in graphic 10, in countries with less than 10 per cent fixed broadband penetration, an increase of 1 per cent in deaths per 100 population generates a contraction of GDP per capita of -0.024 per cent. As for the second group of countries (with penetration 10–30 per cent) the parameter of interaction in the model presented in Table 10 was found to be non-significant. Consequently, the corresponding elasticity is similar to that of unconnected countries. For countries with penetration levels of 30–90 per cent, the elasticity of economic impact diminishes in absolute value, as the connectivity levels in these countries allow for a significant part of the population to telework during lockdowns. For these countries, an increase

[18] We have also tested splitting the 30-90 per cent interval into sub-segments, but no significant statistical differences were found across them.

of 1 per cent in deaths per 100 population generates a contraction of GDP per capita of -0.021 per cent, which means that 15 per cent of the economic damage incurred by low-connected countries is mitigated. Finally, countries with full connectivity levels (90 per cent or above) have the lowest elasticity in economic impact, equal to -0.019 per cent, meaning that they can mitigate 21 per cent of the economic disruption of unconnected or low-connected countries.

Finally, Figure 11 presents a simulation based on the estimated parameters, presenting three hypothetical countries that are similar in all characteristics except one: level of fixed broadband penetration. These three countries all start with a baseline GDP per capita = 100 in the last quarter of 2019 (before the COVID-19 outbreak) and face the pandemic in the same intensity (in all cases, the worldwide averages of mortality ratio for each quarter were applied).

Figure 11: Simulation of GDP per capita evolution (fourth quarter of 2019 = 100) by level of fixed broadband penetration



Source: ITU; analysis by the authors.

As indicated in Figure 11, the economic evolution of each country diverges over time: *ceteris paribus*, the largest output contraction is experienced by the lower connected economies: over time, non-connected countries experience a GDP per capita contraction of -5.4 per cent, while more connected economies undergo a contraction of -3.5 per cent. That represents a substantial difference, equivalent to almost 2 per cent of the GDP per capita.

6.3.2. Impact of mobile broadband in mitigating COVID 19-induced economic disruption

In the case of mobile broadband, dummy variables were assigned to each country, depending on the penetration of unique mobile subscribers per population, as presented in Table 11.

Table 11: Thresholds defined for mobile broadband (MBB) unique subscribers penetration as considered in interaction with the COVID effect

Indicator	Description	Examples
MBB penetration < 10%	Unconnected countries. These are expected to face the worse economic outcomes from the crisis.	Central African Republic
MBB penetration 10%-30%	Low-connected countries. While a certain percentage of the population is connected, this is expected to be insufficient to ensure continued economic activity during lockdowns.	Burkina Faso, Ethiopia, Yemen
MBB penetration 30%-50%	Mid-level connected countries. By surpassing the 30% threshold in mobile broadband, it is assumed that these countries may exhibit some capabilities for migration to teleworking and keeping supply chains running.	Bolivia, Egypt, Lebanon
MBB penetration 50%-75%	High-connected countries. By surpassing the 50% threshold, it is assumed that these countries are able to ensure mass migration to teleworking and keep supply chains running.	Argentina, Chile, Estonia
MBB penetration > 75%	Fully connected countries. These countries are expected to experience a complete process automatization and are believed to be the less affected by lockdowns.	Denmark, Singapore, United States,

Source: Authors.

Table 12 summarizes the econometric results for mobile broadband, indicating again that the more connected a country is, the less economic damage it will incur from the pandemic.

Table 12: Estimate of the mobile broadband structural model

Log (GDP per capita)	
Log (Gross fixed capital formation)	0.144***
	[0.008]
Log (Human capital)	0.048***
	[0.010]
Log (Mobile broadband penetration)	0.155***
	[0.009]
COVID (deaths/100 inhabitants)	-0.265***
	[0.077]
(MBB penetration 10%-30%)*COVID[2]	-0.407
	[2.986]
(MBB penetration 30%-50%)*COVID[2]	0.253
	[0.193]

Table 12: Estimate of the mobile broadband structural model (continued)

(MBB penetration 50%-75%)*COVID[2]	0.231***
	[0.088]
(MBB penetration > 75%)*COVID[2]	0.292*
	[0.153]
Log (Mobile broadband penetration)	
Log (Mobile penetration)	1.696***
	[0.029]
Log (Rural population)	-0.052***
	[0.009]
Log (GDP per capita)	0.044***
	[0.010]
Log (Mobile broadband price)	-0.010
	[0.009]
Log (HHI mobile broadband)	-0.331***
	[0.0158]
Log (Mobile Broadband revenue)	
Log (GDP per capita)	0.516***
	[0.030]
Log (Mobile broadband price)	0.130***
	[0.037]
Log (HHI mobile broadband)	-1.550***
	[0.067]
Log (Mobile broadband adoption growth)	
Log (Mobile broadband revenue)	-0.008***
	[0.000]
Observations	5225
Country fixed effects	Yes
Year and quarter fixed effects	Yes
R-squared (first equation)	0.995

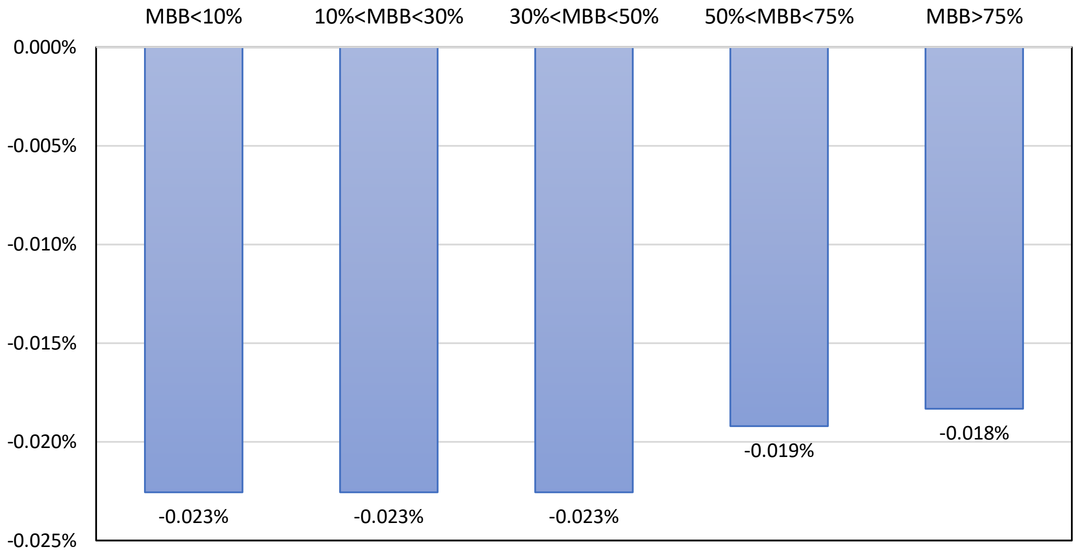
Note: standard errors in parentheses. *p<10%, **p<5%, ***p<1%
Source: Analysis by the authors.

As reported in Table 12, the interaction variables exhibit the following results: non-significant for the 10–30 per cent and 30–50 per cent intervals, which suggests that mobile broadband connectivity levels below 50 per cent are not enough to mitigate the economic damage caused by the pandemic. On the other hand, countries that surpassed the 50 per cent threshold were able to mitigate some of the economic damage, as the interaction term is positive and significant for these economies. Finally, fully connected economies (penetration above 75 per cent) were able to achieve the highest levels of damage mitigation through mobile broadband technology.

An important difference should be highlighted: fixed broadband technology appears to have a greater effect than mobile broadband, in mitigating COVID-induced economic disruption. Fixed broadband is more suited than mobile broadband to support teleworking and the automation of supply chains: having 30 per cent of households connected to fixed broadband already contributes to mitigating a portion of the economic damage, while having 30 per cent of the population connected to mobile broadband does not have the same effect. Mobile broadband needs to reach 50 per cent of the population to have a mitigating effect.

The elasticities of economic impact are presented in Figure 12, following a calculation procedure similar to that used for fixed broadband.

Figure 12: Percentage variation in quarterly GDP per capita after an increase of 1 per cent in COVID deaths per 100 population – by level of mobile broadband penetration

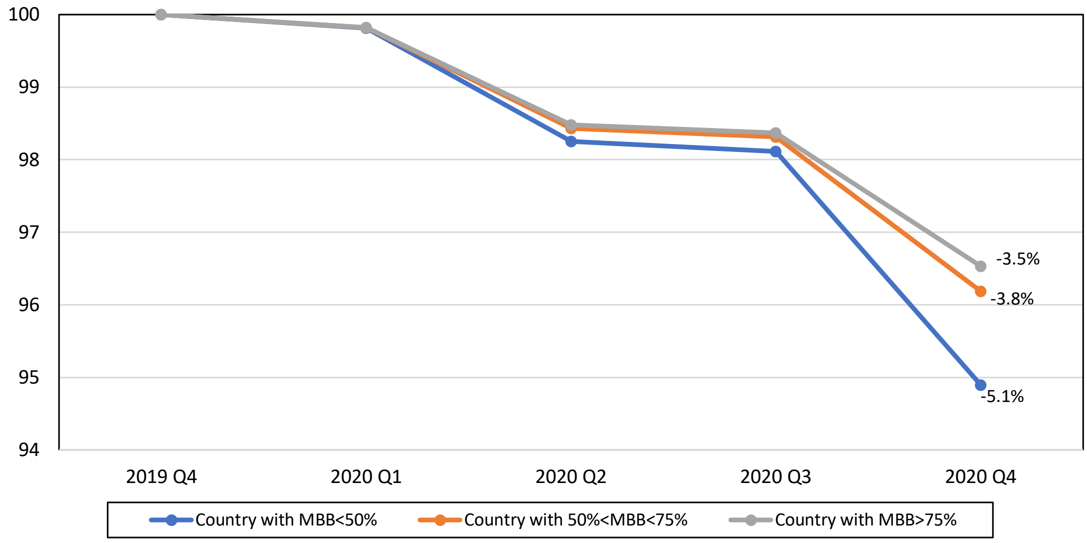


Source: ITU; analysis by the authors.

For all countries with broadband penetration below 50 per cent, the elasticity of economic impact is equal to -0.023 per cent. Only for countries with more than 50 per cent mobile broadband penetration does economic contraction seem to be mitigated by wireless Internet connectivity. For countries with broadband penetration between 50 and 75 per cent, the elasticity of economic impact is lower in absolute value, as such connectivity levels allow the economy to keep running partially. For these countries, an increase of 1 per cent in deaths per 100 population generates a contraction of GDP per capita of -0.019 per cent, which means that in this case 15 per cent of the economic damage attributable for lower connected economies is mitigated. Finally, countries with full connectivity levels (75 per cent of penetration, or above) are those for which this elasticity takes the lowest absolute value, reaching -0.018 per cent, or mitigating 19 per cent of the economic damage corresponding to unconnected or low connected countries.

Again, the elasticity figures reported in Figure 12 highlight the relatively lower relevance of mobile technology in comparison with fixed broadband in such circumstances: while the economies with full fixed broadband connectivity were able to mitigate a larger part of the economic crisis than unconnected countries (21 per cent), in the case of mobile broadband, the corresponding degree of mitigation is 19 per cent. Finally, in Figure 13 we present a simulation, like the one carried out for fixed broadband, which yields equivalent results.

Figure 13: Simulation of GDP per capita evolution (fourth quarter of 2019 = 100) by level of mobile broadband unique subscribers penetration



Source: ITU; analysis by the authors.

According to Figure 13, the largest output contraction is experienced by the lower-connected economies. Over a year, unconnected countries experience a GDP per capita contraction of -5.1per cent, in contrast to -3.5 per cent for more connected economies.

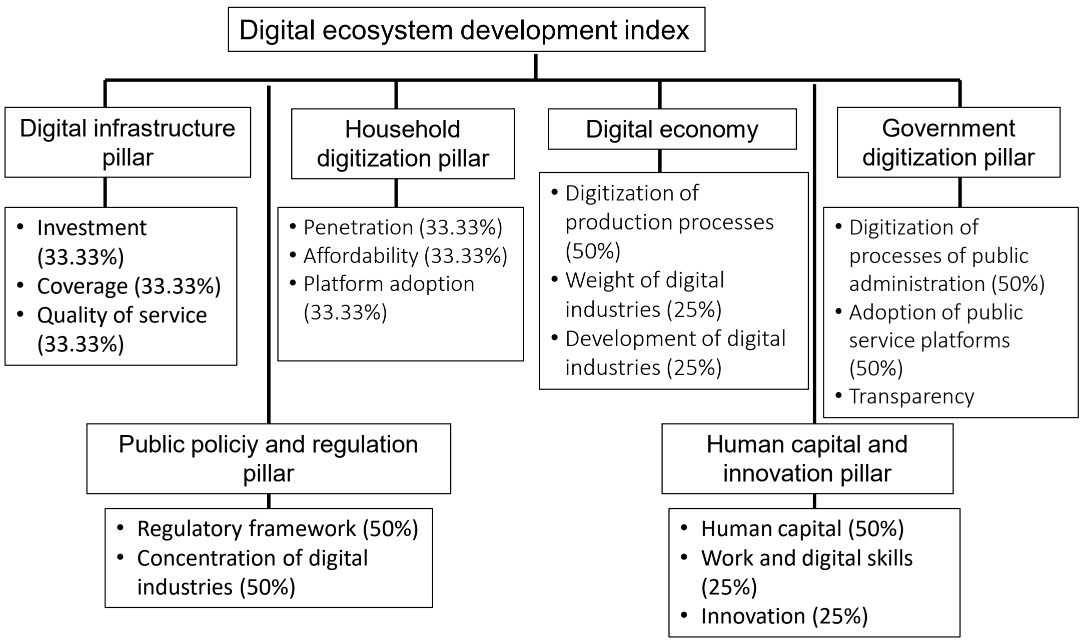
7. Digitization and its impact on the economy through the COVID-19 pandemic

Digitization is the transformation of the techno-economic environment and socio-institutional operations of a nation through the deployment and use of digital technologies and applications. The 2020 study introduced a digitization index that measured the cumulative economic effects of adoption and usage of multiple ICTs across individual users and enterprises, the development of digital industries, and the factors of production of the digital economy, among other factors. This chapter presents a slightly modified index structure, recalculates its evolution since 2010 for consistency, and develops econometric models to estimate the impact of digitization on GDP and productivity.

7.1. A new measurement of digitization

Since the 2020 study, a new index has been developed aiming to capture better the new dimensions of the digital economy. The new index is based on six pillars and 107 indicators (see Figure 14)

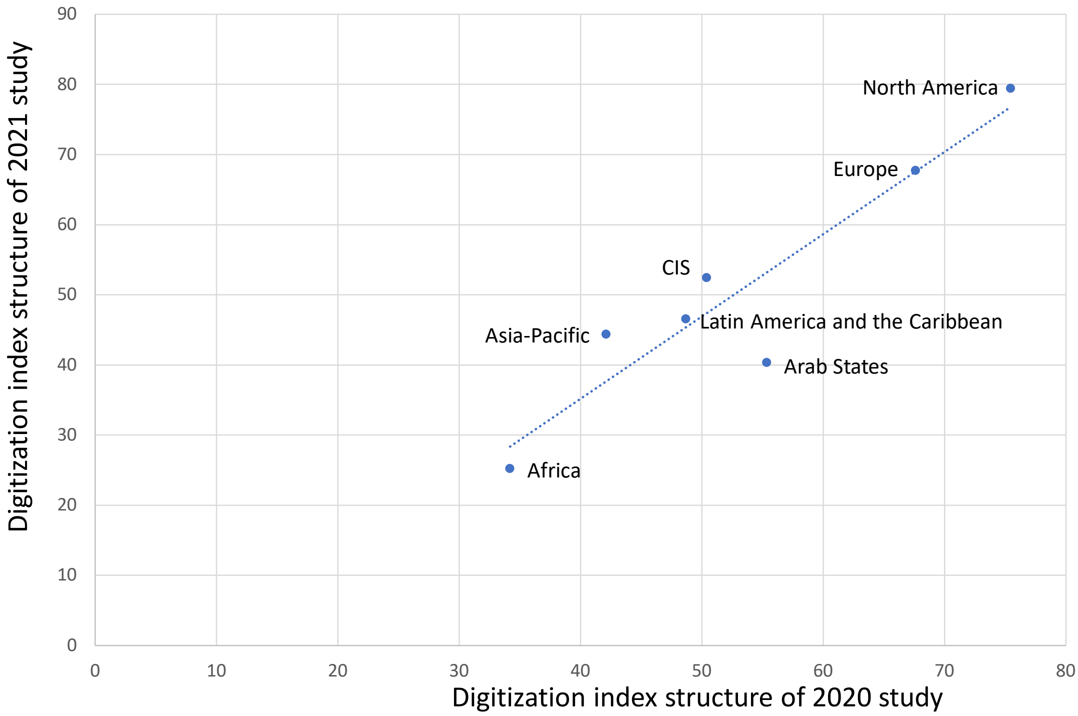
Figure 14: Digital ecosystem index structure



Source: CAF – Latin America development Bank.

A comparison of the previous and new indices for 2018 indicates a high level of consistency (see Figure 15).

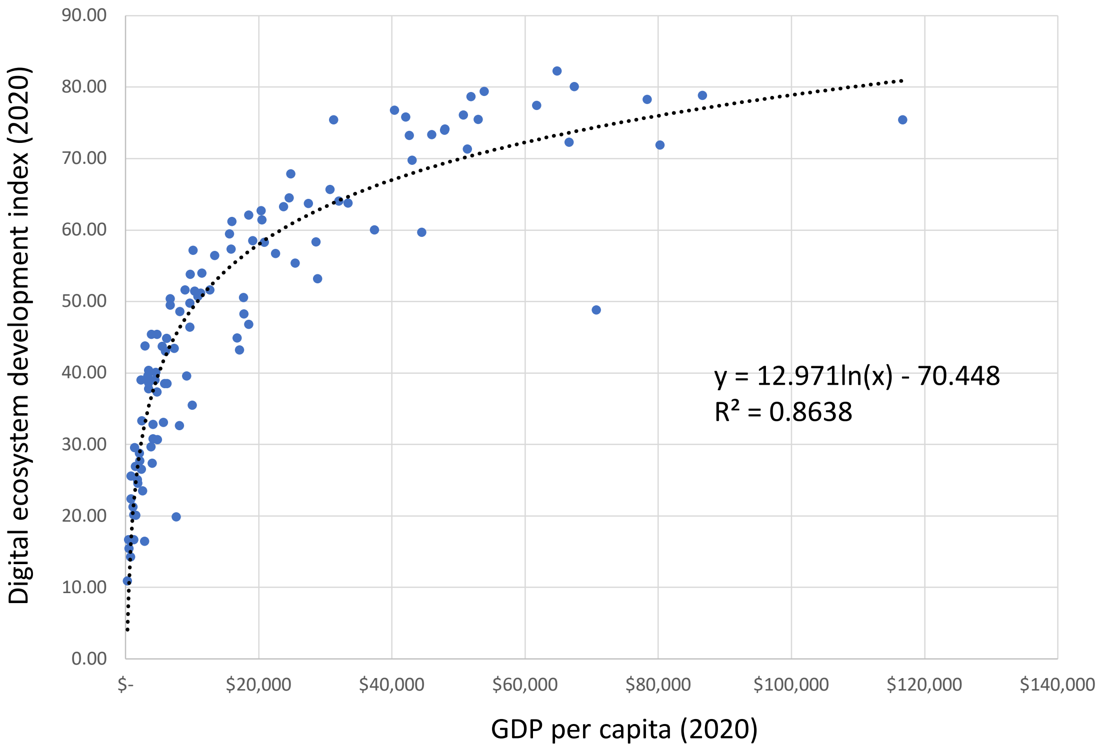
Figure 15: Correlation between both indices of digital ecosystem for 2018



Source: ITU; analysis by the authors.

The index has been recalculated to reflect the pandemic's impact, during 2020, on the main pillars. As in the 2020 study version, the newly developed digital ecosystem index correlates with economic development (see Figure 16).

Figure 16: Correlation between GDP per capita and digital ecosystem development index, 2020



Sources: IMF; analysis by the authors.

7.2. Digitization and its impact on the economy up to 2018

In the 2020 study, the economic impact of digitization was tested using two econometric models run on data for 73 countries.[19] An endogenous growth model was used to test the impact of digitization on GDP growth and was based on the Cobb-Douglas production function:

$$\text{Log}(GDP_{it}) = a_1\log(\text{Capital}_{it}) + a_2\log(\text{Labour force}_{it}) + a_3\log(\text{digitization index}_{it}) + a_4\log(\text{previous year GDP})\,\varepsilon_{it}$$

In addition, a model for testing the impact of digitization on productivity was based on the following model:

$$\text{Log}(\text{Productivity}_{it}) = a_1\log(\text{Growth of digitization}_{it}) + a_2\log(\text{digitization index}_{it}) + \varepsilon_{it}$$

The results of the models run on the prior version (2018) of the index indicated the following:

- On a global scale, digitization makes a more significant economic contribution than fixed broadband, on a par with that of mobile broadband: 1 per cent increase in the digitization index is associated with 0.1331 increase in GDP per capita.

[19] The economies included Argentina, Australia, Austria, Azerbaijan, Barbados, Belarus, Belgium, Bolivia, Brazil, Bulgaria, Canada, China, Chile, Colombia, Côte d'Ivoire, Czech Republic, Denmark, Ecuador, Egypt, El Salvador, Estonia, Finland, France, Germany, Greece, Guatemala, Haiti, Honduras, Hong Kong (China), Hungary, Iceland, India, Ireland, Israel, Italy, Jamaica, Japan, Kazakhstan, Kenya, Latvia, Lebanon, Luxembourg, Malaysia, Mexico, the Netherlands, New Zealand, Nicaragua, Norway, Panama, Paraguay, Peru, Poland, Portugal, Republic of Korea, Romania, Russian Federation, Saudi Arabia, Singapore, Slovakia, Slovenia, South Africa, Spain, Sweden, Switzerland, Thailand, Trinidad and Tobago, Turkey, United Arab Emirates, the United Kingdom, the United States, Uruguay and Venezuela.

- The impact of digitization on advanced economies is higher than on emerging economies, confirming the "returns to scale" effect: a 10 per cent increase in the digitization index yields an increase of 1.351 per cent of GDP in OECD countries and 1.044 per cent in non-OECD countries.
- Digitization boosts labour productivity: 10 per cent digitization yields an increase of 2.62 per cent. A 10 per cent increase yields an increase of 2.28 per cent in total factor productivity.

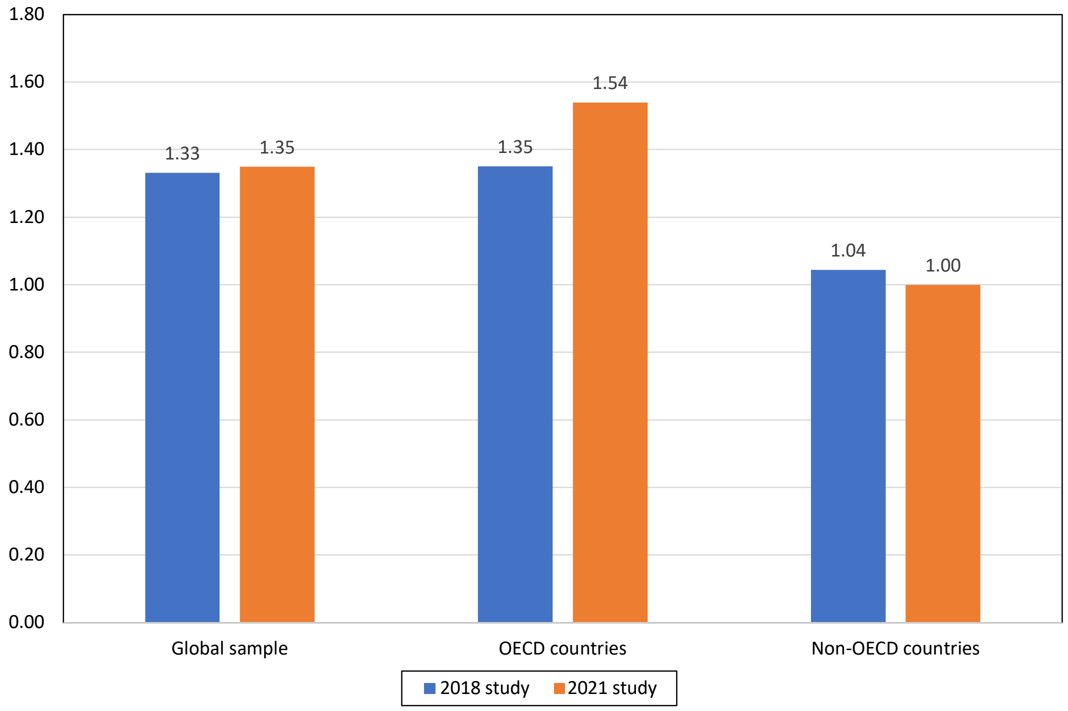
7.3. Digitization and its impact on the economy through the pandemic

By relying on the same model used in the 2020 study, the economic impact of digitization to the end of 2020 was estimated along two variables: GDP growth and productivity.

Digitization and GDP growth

The impact on GDP growth was tested through a generalized method of moments panel data model run for 107 countries extending between 2004 and 2020 both for the global sample and for OECD and non-OECD countries (in the last case, the series started in 2005) with the following results. Figure 17 compares the results of this analysis with those generated in the 2020 study.

Figure 17: Impact on GDP of 10 per cent increase in digital ecosystem development index



Source: ITU; analysis by the authors.

As indicated in Figure 17, the results of the current study models are consistent with the 2018 estimates. First, the digital ecosystem index impact on a global scale is consistent with the 2018 result (1.35 per cent vs. 1.33 per cent). Second, as demonstrated in the previous study, the impact of the digital index on developed countries is higher than on developing countries (1.54 per cent vs. 1.00 per cent for OECD countries), confirming the "returns to scale" effect.

Digitization and productivity

To measure the impact on labour productivity, the starting point was a Cobb-Douglas production function, where GDP (Y) depends on physical capital stock (K) and labour (L):

$$Y = AK^{\alpha}L^{\beta}$$

Where the total factor productivity term (A) depends on the degree of digitization of each country: $A = \mu DIGITIZATION^{\Upsilon}$. By assuming constant returns to scale on capital and labour, the function was converted to state that labour productivity depends on digitization and on physical capital stock per worker (we use lower case letters y and k to denote output and capital in per worker terms). By applying logarithms for linearization, the following model was defined:

$$\log(y) = \log(\mu) + \Upsilon \log(DIGITIZATION) + \alpha \log(k)$$

Where $\log(\mu)$ is a fixed effect assumed to be specific for each country. The linear regression estimate is performed for a sample of 107 countries for the period 2009–2020.

Table 13: Fixed effects regression of labour productivity on capital per worker and digitization

Dependent variable: log(y)	Coefficient
$\log(DIGITIZATION)$	0.250***
	[0.091]
$\log(k)$	0.389***
	[0.090]
Country fixed effects	YES
Year fixed effects	YES
R-squared (within)	0.499
Observations	1256

Note: *** p<1%. Robust standard errors in brackets.
Source: Analysis by the authors.

The results indicate that a 10 per cent increase in the digitization index is associated with a 2.5 per cent increase in labour productivity. This result does not differ from that calculated in the 2020 study, where the coefficient of increase on labour productivity was 2.6 per cent.

As stated initially, the total factor productivity term depends on the digitization level of each country, plus an individual fixed effect for each economy. By applying logarithms, this can be expressed as:

$$\log(A) = \log(\mu) + \Upsilon \log(DIGITIZATION)$$

The corresponding regression yields the following results:

Table 14: Fixed effects regression of total factor productivity on digitization

Dependent variable: log(*A*)	Coefficient
$\log(DIGITIZATION)$	0.188**
	[0.092]
Country fixed effects	YES
Year fixed effects	YES
R-squared (within)	0.045
Observations	1223

Note: ** p<5%. Robust standard errors in brackets.
Source: Analysis by the authors.

This means that a 10 per cent increase in the digitization index is associated with a 1.9 per cent increase in total factor productivity. In the 2020 study, the coefficient of impact in total factor productivity was 2.3 per cent.

The consistency of results between the 2020 and 2021 studies regarding the economic impact of digitization reinforces the importance of countries developing their digital economy, an agenda for which should comprise the following five areas of policy intervention.

- Digital infrastructure: ICT capital spending, increased connectivity and affordability.
- Digital human capital: development of digital skills to match the changing needs of economies undergoing digital transformation.
- Digital innovation relating to scale of research and development and fostering incubation ecosystems.
- Digital adoption: adoption of ICT services, devices and digital platforms by individuals, governments and enterprises.
- Development of domestic digital sector: incubation of local sectors offering digital products and services both for local consumption and export.

8. Conclusions and policy implications

This research has shown that the ICT ecosystem has changed significantly since the completion of the 2020 study, partly as a result of COVID-19. Below are the most noticeable trends identified in 2020.

- Internet traffic worldwide has increased by approximately 30 per cent, with changes to time of day and geographic distribution patterns (including a shift from enterprise to residential access, a portion of traffic shifting from mobile broadband to fixed broadband/Wi-Fi, and sustained traffic levels throughout the day).
- Telecommunication/ICT capital investment in advanced economies has accelerated (from 0.5 CAGR in 2010–2019 to 1.8 per cent in 2019–2020 in OECD countries) to accommodate the increase in traffic, combined with the deployment of 5G and optical fibre infrastructure.
- Telecommunication/ICT capital investment in developing countries has, however, declined (3.6 per cent between 2019 and 2020 in Latin America and the Caribbean, 1.4 per cent in Asia and the Pacific, 1.7 per cent in the Arab States, and 3.6 per cent in Africa), thereby indicating a widening of the digital divide.
- The decline of CAPEX per capita in developing countries has resulted in a decreasing growth rate of 4G coverage and lagging deployment of 5G (5G currently reaching 3.34 per cent of the population in Latin America and the Caribbean, and 0 per cent of the population in Africa).
- Fixed broadband adoption has continued to grow around the world (from 53.3 per cent of households to 58.5 per cent in Latin America and the Caribbean, from 53.2 per cent to 55.2 per cent in Asia and the Pacific, from 62.4 per cent to 67.0 per cent in the Arab States, from 66.7 per cent to 72.1 per cent in CIS, and even from 84.4 per cent to 87.6 per cent in Europe) in response to the need to accommodate teleworking, distance learning, remote entertainment, and telemedicine.
- Broadband prices have continued to fall, which even in the context of declining incomes, has increased affordability (worldwide fixed broadband prices as a percentage of GNI per capita dropped by 1.7 per cent and mobile broadband prices decreased by 2.6 per cent).[20]
- Digital platforms have undergone more intense use driven by pandemic-induced lockdowns. For example, the use of e-commerce has increased from a worldwide average of 9.5 per cent of total retail trade in 2019 to 12.4 per cent in 2020.[21]

Changes in the ICT ecosystem driven by the disruption of the pandemic (continuing capital spending on roll-out, jump in broadband penetration, decline in pricing, especially for mobile broadband) have confirmed the importance of ICTs as a driver of economic growth. For example, the percentage increase in per capita GDP resulting from an increase in 10 per cent broadband penetration on a worldwide basis has remained largely stable both for fixed (0.77 per cent to 0.80 per cent) and mobile broadband (from 1.50 per cent to 1.60 per cent). Similarly, the contribution of fixed broadband continues to be greater in developed countries (1.25 per cent increase in GDP per capita as a result of 10 per cent increase in broadband penetration) than in developing countries (0.85 per cent in middle-income countries and non-significant results in low-income countries), reflecting the "return to scale" effect. In addition,

20 ITU World Telecommunications/ICT Indicators (WTI) Database 2021.
21 Euromonitor (2021).

the economic dividend of mobile broadband continues to be greater in countries with lower levels of economic development (2.04 per cent increase in GDP per capita as a result of 10 per cent increase in broadband penetration, diminishing in countries and regions with higher levels of broadband penetration and development (1.62 per cent in middle income countries and non-significant results in high-income countries).

A similar effect was proven using a digitization index that captures all dimensions of the digital economy. On a global scale, digitization has a larger economic contribution than fixed broadband, on a par with that of mobile broadband: 10 per cent increase in the digitization index is associated with 1.35 per cent increase in GDP per capita. In addition, the impact of digitization on advanced economies is higher than on emerging economies, confirming the "returns to scale" effect: 10 per cent increase in the digitization index yields an increase of 1.54 per cent in GDP for OECD countries and 1.00 per cent for non-OECD countries.

Furthermore, the analyses presented in this study have relied on empirical evidence to highlight the important role digital technology is playing in mitigating the economic disruption caused by COVID-19. Results appear robust in pointing out that, in 2020, countries with higher broadband penetration were able to counteract a portion of the economic losses incurred during the pandemic. Thus, a reliable telecommunication and ICT infrastructure, and a high level of digitization seem crucial to keep the economy running under pandemic conditions.

These results back up the measures taken in countries in the context of the emergency to enable telecommunication operators to accommodate the resulting increases in Internet traffic. Examples of this are the policy carried out by many governments that temporarily granted mobile operators the use of additional spectrum in pre-determined regions of the country, or the traffic reduction temporally applied by some streaming providers by reducing the definition of video content. In the longer run, countries will have to prepare themselves in terms of the development of a digital infrastructure to face similar future situations. In that respect, the promotion of national emergency telecommunication plans[22] and digital resilience plans to prepare for future pandemic disruptions, and the creation of a suitable regulatory framework to stimulate private investments for closing the digital supply gap, seem to be crucial initiatives.

Furthermore, the evidence generated in this study provides additional guidance for forward-looking actions. Policy-makers and regulators in developing countries need to evaluate initiatives to reverse the declining capital spending trend and stimulate telecommunication and ICT investment to ensure continuous roll-out of networks.[23] The importance of ICTs in mitigating some of the economic damage caused by pandemics highlights the need for governments to reduce demand-side barriers (affordability, digital literacy, local content development) and stimulate mobile broadband adoption.

Finally, the high value of fixed broadband as a mitigant of pandemic-induced economic disruption highlights the urgent need for countries with underdeveloped fixed connectivity to explore how to foster the roll-out of networks, with an initial emphasis on high density urban concentrations.

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22 See the ITU Guidelines for national emergency telecommunication plans. Available at: https://www.itu.int/en/ITU-D/Emergency-Telecommunications/Pages/Publications/Guidelines-for-NETPs.aspx

23 See ITU (2021). *The impact of policies, regulation, and institutions on ICT sector performance.* Available at: https://www.itu.int/en/ITU-D/Regulatory-Market/Pages/Economic-Contribution.aspx.

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Appendices

A.1. Fixed broadband models: Global sample

	Global model	High-income	Middle-income	Middle-income (from 2013)	Low-income
Log (GDP per capita)					
Log (Gross fixed capital formation)	0.109***	0.226***	0.136***	0.240***	0.110***
	[0.010]	[0.016]	[0.019]	[0.030]	[0.027]
Log(Education)	0.051***	-0.116***	0.061***	0.038	0.094***
	[0.011]	[0.018]	[0.019]	[0.025]	[0.018]
Log (Fixed broadband penetration)	0.080***	0.125***	0.011	0.085***	-0.022
	[0.012]	[0.031]	[0.010]	[0.020]	[0.031]
Log (Fixed broadband penetration)					
Log (Fixed telephone penetration)	0.447***	0.343***	0.291***	0.362***	
	[0.013]	[0.017]	[0.037]	[0.038]	
Log (Mobile penetration)	-0.312***				
	[0.008]				
Log (Rural population)	-0.083***	0.051***	-0.147***	-0.112***	-1.197***
	[0.021]	[0.011]	[0.036]	[0.037]	[0.061]
Log (GDP per capita)	0.882***	0.469***	0.816***	0.647***	1.100***
	[0.021]	[0.026]	[0.155]	[0.163]	[0.048]
Log (Fixed broadband price)	-0.416***	-0.053***	-0.586***	-0.389***	-0.454***
	[0.012]	[0.010]	[0.028]	[0.028]	[0.023]
Log (HHI fixed broadband)	-0.500***	-0.087***	-0.350***	-0.419***	-0.368***
	[0.018]	[0.015]	[0.035]	[0.043]	[0.028]
Log (Fixed broadband revenue)					
Log (GDP per capita)	1.301***	0.118	-1.715***	-1.967***	1.521***
	[0.022]	[0.112]	[0.347]	[0.400]	[0.052]
Log (Fixed broadband price)	0.375***	0.989***	0.176***	0.416***	0.361***
	[0.021]	[0.046]	[0.063]	[0.070]	[0.027]
Log (HHI fixed broadband)	-0.869***	-1.065***	-0.986***	-1.271***	-0.800***
	[0.032]	[0.068]	[0.078]	[0.101]	[0.034]
Broadband adoption growth					
Log (Fixed broadband revenue)	-0.446***	-0.204*	-0.185*	-0.153	-0.312***
	[0.043]	[0.116]	[0.091]	[0.095]	[0.102]
Observations	5328	1865	1099	813	2475

(continued)

	Global model	High-income	Middle-income	Middle-income (from 2013)	Low-income
Number of countries	139	50	26	26	63
Country fixed effects	Yes	Yes	Yes	Yes	Yes
Year and quarter fixed effects	Yes	Yes	Yes	Yes	Yes
R-squared first model	0.992	0.971	0.858	0.834	0.978
Period	2010-2020	2010-2020	2010-2020	2013-2020	2010-2020

A.2. Fixed broadband models: Regional models

	Africa	Europe (low income)	CIS	Arab States	Latin America and the Caribbean	Asia and the Pacific	Americas (including North America)	Europe (high income)
Log (GDP per capita)								
Log (Gross fixed capital formation)	0.035*	0.092***	0.141**	0.112***	0.254***	0.111***	0.132***	0.387***
	[0.018]	[0.032]	[0.066]	[0.021]	[0.019]	[0.019]	[0.034]	[0.032]
Log (Education)	0.011	0.008	0.032	0.082**	0.098***	0.158***	0.059**	-0.273***
	[0.014]	[0.027]	[0.106]	[0.035]	[0.031]	[0.032]	[0.023]	[0.054]
Log (Fixed broadband penetration)	0.004	0.046*	0.077**	0.053*	0.147***	0.153***	0.197***	0.293***
	[0.011]	[0.025]	[0.034]	[0.032]	[0.042]	[0.030]	[0.056]	[0.051]
Log (Fixed broadband penetration)								
Log (Fixed telephone penetration)	0.384***	0.407***	2.230***	0.717***	0.290***	0.025**	0.716***	0.120***
	[0.022]	[0.044]	[0.138]	[0.052]	[0.051]	[0.013]	[0.038]	[0.015]
Log (Mobile penetration)				0.326***				
				[0.072]				
Log (Rural population)	-0.734***	0.042	5.957***	-0.053*	-0.016	-0.035	-0.044***	-0.064***
	[0.083]	[0.062]	[0.629]	[0.032]	[0.023]	[0.033]	[0.017]	[0.009]
Log (GDP per capita)	0.445***	0.363***	0.315	0.439***	0.801***	2.482***	0.470***	0.190***
	[0.062]	[0.020]	[0.303]	[0.052]	[0.050]	[0.130]	[0.030]	[0.015]
Log (Fixed broadband price)	-0.226***	-0.116***	-0.131**	-0.387***	-0.366***	-0.061***	-0.204***	-0.098***
	[0.035]	[0.017]	[0.059]	[0.031]	[0.022]	[0.014]	[0.014]	[0.010]
Log (HHI Fixed broadband)	-0.506***	-0.121***	-0.020	0.026	-0.008	-0.060*	0.003	-0.062***
	[0.048]	[0.029]	[0.050]	[0.052]	[0.029]	[0.036]	[0.021]	[0.018]
Log (Fixed broadband revenue)								
Log (GDP per capita)	0.535***	0.364***	0.978***	0.316***	0.747***	2.722***	1.299***	0.275***
	[0.063]	[0.063]	[0.072]	[0.058]	[0.131]	[0.132]	[0.116]	[0.100]
Log (Fixed broadband price)	0.499***	1.073***	-3.415***	0.305***	0.753***	0.937***	0.580***	1.318***
	[0.041]	[0.056]	[0.136]	[0.058]	[0.070]	[0.015]	[0.074]	[0.069]
Log (HHI fixed broadband)	-1.011***	-0.078	-0.768***	0.569***	-1.213***	-0.050	-1.398***	-0.960***
	[0.055]	[0.090]	[0.054]	[0.096]	[0.090]	[0.036]	[0.105]	[0.106]
Broadband adoption growth								
Log (Fixed broadband revenue)	0.141	-0.308**	-0.361**	-0.154	0.136	1.669***	-0.138***	-0.108**
	[0.124]	[0.135]	[0.158]	[0.121]	[0.128]	[0.214]	[0.047]	[0.044]
Observations	1265	742	232	520	868	624	668	1342
Number of countries	32	14	8	15	15	34	17	22
Country fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year and quarter fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared first model	0.992	0.981	0.983	0.993	0.972	0.995	0.989	0.919

A.3. Mobile broadband models: Global sample

	Global	Low-income countries	Middle-income countries	High-income countries
Log (GDP per capita)				
Log (Gross fixed capital formation)	0.137***	0.120***	0.160***	0.172***
	[0.009]	[0.014]	[0.019]	[0.011]
Log (Education)	0.048***	0.094***	0.074***	-0.098***
	[0.011]	[0.018]	[0.021]	[0.019]
Log (Mobile broadband penetration)	0.160***	0.204***	0.162***	-0.004
	[0.009]	[0.020]	[0.034]	[0.090]
Log (Mobile broadband penetration)				
Log (Mobile penetration)	1.694***	1.754***	1.432***	1.536***
	[0.029]	[0.040]	[0.069]	[0.060]
Log (Rural population)	-0.052***	0.032	-0.085***	-0.005
	[0.009]	[0.028]	[0.013]	[0.008]
Log (GDP per capita)	0.046***	0.011	0.027	0.243***
	[0.010]	[0.019]	[0.055]	[0.024]
Log (Mobile broadband price)	-0.012	-0.038**	-0.008	0.009
	[0.009]	[0.016]	[0.017]	[0.011]
Log (HHI mobile broadband)	-0.331***	-0.257***	-0.709***	-0.331***
	[0.016]	[0.022]	[0.036]	[0.028]
Log (Mobile broadband revenue)				
Log(GDP per capita)	0.517***	0.691***	-3.223***	1.168***
	[0.030]	[0.042]	[0.333]	[0.154]
Log (Mobile broadband price)	0.129***	0.020	-0.023	0.287***
	[0.037]	[0.051]	[0.109]	[0.076]
Log (HHI mobile broadband)	-1.547***	-1.245***	-3.289***	-1.711***
	[0.067]	[0.073]	[0.213]	[0.188]
Mobile broadband adoption growth				
Log (Mobile broadband revenue)	-0.008***	-0.009***	-0.003***	-0.005***
	[0.000]	[0.001]	[0.000]	[0.000]
Observations	5227	2320	901	1729
Number of countries	129	58	26	45

(continued)

	Global	Low-income countries	Middle-income countries	High-income countries
Country fixed effects	Yes	Yes	Yes	Yes
Year and quarter fixed effects	Yes	Yes	Yes	Yes
R-squared first model	0.993	0.974	0.876	0.977

A.4. Mobile broadband models: Regional models

	Africa	Europe (lowincome)	CIS	Arab States	Latin America and the Carib-bean	Asia and the Pacific (low- and middle-income)	Asia-Pacific	Americas (includ-ing North America)	Europe (highin-come)
Log (GDP per capita)									
Log (Gross fixed capital formation)	-0.017	-0.031	0.158**	0.075***	0.145***	0.037*	0.126***	0.146***	0.102**
	[0.016]	[0.036]	[0.065]	[0.023]	[0.034]	[0.020]	[0.025]	[0.035]	[0.051]
Log (Education)	-0.029*	0.030	-0.195**	0.127**	0.087***	0.026*	0.152***	0.065***	-0.010
	[0.015]	[0.038]	[0.090]	[0.051]	[0.030]	[0.015]	[0.021]	[0.019]	[0.115]
Log (Mobile broadband penetration)	0.260***	0.189**	0.165***	0.181***	0.170***	0.248**	0.106*	0.127**	0.697
	[0.050]	[0.090]	[0.063]	[0.030]	[0.044]	[0.113]	[0.061]	[0.057]	[0.534]
Log (Mobile broadband penetration)									
Log (Mobile penetration)	0.991***	1.077***	0.866***	1.383***	-0.581*	-0.004	-0.018***	0.441***	0.706***
	[0.044]	[0.069]	[0.223]	[0.076]	[0.301]	[0.007]	[0.002]	[0.126]	[0.043]
Log (Rural population)	0.127***	0.274***	-0.875	-0.003	0.114	0.279*	-0.016	-0.160***	-0.009**
	[0.024]	[0.036]	[1.061]	[0.019]	[0.092]	[0.156]	[0.033]	[0.024]	[0.004]
Log (GDP per capita)	0.220***	0.184***	0.503	0.200***	1.198***	0.853***	0.514***	0.261***	0.116***
	[0.016]	[0.014]	[0.546]	[0.024]	[0.406]	[0.173]	[0.025]	[0.042]	[0.014]
Log (Mobile broadband price)	-0.133***	-0.018	-0.098***	0.002	-0.157***	0.013	-0.096***	-0.132***	-0.082***
	[0.011]	[0.014]	[0.026]	[0.019]	[0.036]	[0.008]	[0.016]	[0.032]	[0.017]
Log (HHI mobile broadband)	-0.064***	-0.285***	-0.029	-0.559	-0.006	0.022	-0.023	-0.460***	-0.119***
	[0.021]	[0.042]	[0.099]	[0.049]	[0.086]	[0.023]	[0.037]	[0.058]	[0.016]
Log (Mobile broadband revenue)									
Log (GDP per capita)	0.381***	1.384***	0.925***	-1.292***	1.234***	8.089***	1.363***	3.437***	0.324
	[0.055]	[0.044]	[0.053]	[0.283]	[0.392]	[0.232]	[0.251]	[0.459]	[0.254]
Log (Mobile broadband price)	0.266***	1.030***	1.275***	0.757***	0.791***	0.778***	1.302***	0.930***	-0.494
	[0.054]	[0.048]	[0.073]	[0.042]	[0.067]	[0.066]	[0.039]	[0.057]	[0.311]
Log (HHI mobile broadband)	-0.661***	-0.962***	-3.787***	-2.948***	-0.029	-0.205**	-0.251***	-0.092	-0.707**
	[0.104]	[0.104]	[0.189]	[0.160]	[0.153]	[0.081]	[0.043]	[0.193]	[0.298]
Mobile broadband adoption growth									
Log (Mobile broadband revenue)	-0.004***	-0.025***	-0.001	-0.012***	0.015**	-0.018***	0.003*	-0.008***	0.000**
	[0.001]	[0.001]	[0.003]	[0.001]	[0.006]	[0.001]	[0.002]	[0.001]	[0.000]
Observa-tions	919	631	367	580	639	560	768	645	636
Number of countries	32	15	9	18	16	14	19	17	23
Country fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year and quarter fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared first model	0.994	0.980	0.985	0.984	0.958	0.992	0.996	0.988	0.918

A.5. Digitization models

	Global model	OECD model	non-OECD model
Log (GDP per capita) t-1	0.758***	0.663***	0.766***
	[0.027]	[0.037]	[0.033]
Log (Gross fixed capital formation)	0.109***	0.127***	0.107***
	[0.010]	[0.030]	[0.012]
Log (Human capital)	-0.027	-0.058***	0.033
	[0.022]	[0.016]	[0.034]
Log (Digitization index)	0.135***	0.154*	0.100**
	[0.049]	[0.085]	[0.046]
Year fixed effects	Yes	Yes	Yes
Observations	1080	510	570
Period	2004-2020	2004-2020	2005-2020

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